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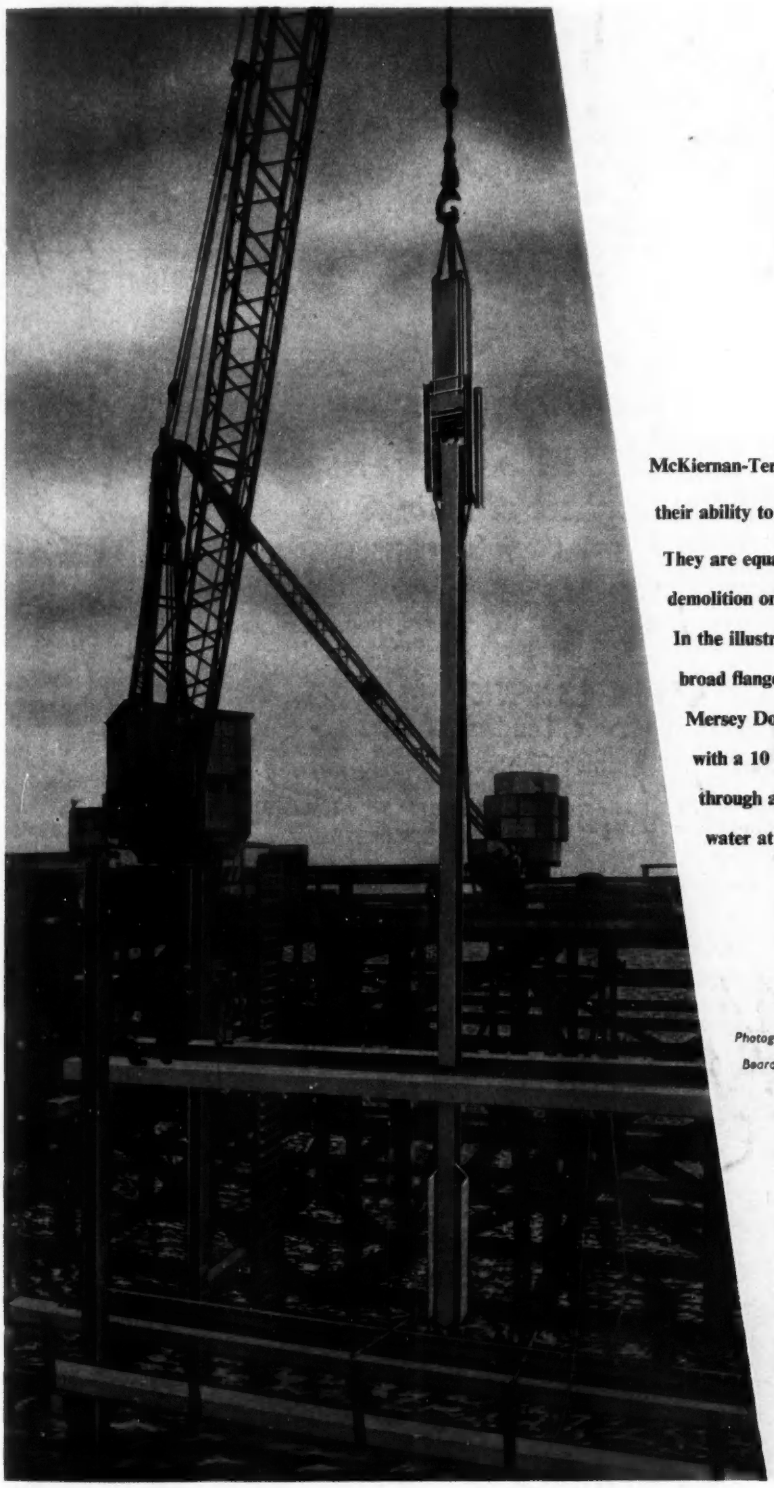

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Photograph by courtesy of the Board's Engineer-in-Chief.

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THE ENGINEER

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ENGINEERS AND METALLURGISTS

No matter how clever or original a designer may be, he cannot escape the fundamental limitations inherent in the things he uses. Indeed, part of the whole art of engineering design is to achieve an objective despite such restrictions. In some fields we have reached the stage where overall performance of a particular kind of plant or equipment can only be improved if new materials can be developed. It may, for example, be that higher working temperatures must be withstood if greater thermodynamic efficiency is to be gained ; or perhaps an alloy with greater mechanical strength is required in order to permit higher power-to-weight ratios to be achieved. Then there are other fields where the gain from the use of new materials is less spectacular though by no means unimportant. There are plants, for instance, where the performance is quite satisfactory and probably cannot be improved ; or it may be a static structure that is perfectly capable of meeting the duty required. In these cases the designer will have achieved his objective by making sure that he has used the materials available to him in such a way that none is overtaxed. But if he could "re-optimise" his design, with materials with properties more suited to his needs, then it might be possible to effect marked savings in the cost of his plant. Nowhere are these facts more true to-day than in the field of nuclear power. It is no exaggeration to say that successful future developments must rest to a very large extent on metallurgical studies. New materials need to be found to make possible some of the developments that are essential to ultimate success, and at the same time much work still needs to be done to give engineers that greater flexibility in design that will lead to cheaper and better plants.

The reactor designer must inevitably set the metallurgist many difficult problems. In considering the overall design of the plant, he would, for example, like to use a fuel element that he could leave in the reactor for as long as possible and thus reduce process recycling costs. He would also like this fuel element to remain dimensionally stable throughout its life. He would require its mechanical properties not to alter appreciably so that it could be handled as safely at the end of its time in the reactor as at the beginning. Yet consider what happens to the fuel element. The fuel structure itself is being torn by nuclear fission. Atoms of uranium are being replaced by atoms of fission products which may be larger than the atoms they replace. Some of the fission products are gases, and these may diffuse out through the fuel or remain locked up inside it at high pressure. While this is happening the fuel is being held at a temperature of several hundred degrees Centigrade with a marked temperature gradient from the centre to the periphery. Under these circumstances it is not surprising that the behaviour of the fuel is difficult to predict, and experiments have shown that some fuels swell and distort badly under irradiation. Again, when one considers the fuel canning material the metallurgical problems are extensive. The material must be compatible with the fuel and the coolant. It must have a low neutron absorption cross-section ; and, as it may have to support the fuel, its mechanical properties ought not to vary very much with irradiation. Some of these same problems apply equally well to the rest of the reactor system. The material used for a reactor vessel has to withstand intense irradiation, as will any other part of the structure in a reactor core.

It was the closeness of this link between engineers and metallurgists in the design of nuclear reactors that led us to comment in a leading article in our issue of December 9, 1955, on what we considered to be a weakness in the composition of the British Nuclear Energy Conference ; namely, the absence of any metallurgical representation. This omission has now, happily, been made good and we welcome the decision of the B.N.E.C. to admit to membership the Iron and Steel Institute and the Institute of Metals. It cannot help but increase the importance and standing of the B.N.E.C. in this field. Already the B.N.E.C. has sponsored some excellent papers and the Symposium on Calder Hall gave an unexampled review of how a project had been developed and brought to fruition. So far the greater proportion of the papers has had to come from members of the United Kingdom Atomic Energy Authority. Now that more and more industrial firms, however, are drawn into the orbit of nuclear power, it is to be hoped that papers will be forthcoming from a wider field. Without destroying or weakening any of the professional organisations to which its members belong, the B.N.E.C. serves to bring together the many interests which collectively must make a success of nuclear power development. Should this pattern be followed in any other field ? Undoubtedly it is right that mechanical engineers or any other professional group should gather together to

discuss their own engineering methods and experiences in a variety of, what may sometimes be unrelated, industries. They thus obtain an interchange of specialist information and maintain professional standards. But many of the real advances are made to-day, not by engineers alone, but by combined teams of engineers and scientists, with the engineers as the ultimate executives. It is this modern trend which the B.N.E.C. reflects.

WORLD OIL SUPPLIES

On August 27, 1859, Edwin Laurentine Drake, a retired American railroad conductor, struck oil—at a depth of 69ft—in a well which had been drilled under his supervision at Titusville, Pennsylvania. This was the first time that petroleum was tapped at its source and the first proof of the occurrence of oil reservoirs within the earth's surface. Drake's foremost contribution to the development of oil-well technique was the use of pipe driven to bedrock to prevent the overburden of clay and quicksand from filling the drill-hole. The idea was not patented and Drake failed to reap any financial benefit from his epoch-making labours, he and his family being supported, in the end, by charitable grants. We are reminded of this piece of technological history by perusal of the paper entitled " World Oil Supplies," read on January 17 before the Diesel Engineers and Users Association by Mr. M. E. Hubbard, of the British Petroleum Company, Ltd. The supply of petroleum is, at the moment, a major concern not only of engineers, but of politicians. The magnitude of the hazard is brought home to us when we realise how, less than one hundred years from the date upon which petroleum first trickled from the well at Titusville, Pennsylvania, the annual world consumption of oil has risen to 786 million tons. In quoting this figure Mr. Hubbard adds to its significance by pointing out (*a*) that since the second world war oil consumption outside the United States of America has been increasing at the rate of 11 per cent per annum, and (*b*) that the oil industry, basing its forward thinking on consumption continuing to rise at this high rate, is, at the present time, investing nearly £3000 million per annum, an expenditure undertaken " mainly to expand facilities." It is hardly to be wondered at that by reason of the ever-growing pressure on the oil industry to provide (in addition to liquid fuel for small and mobile power or heat units) fuel required to meet the basic energy demand formerly taken from coal, the industry has been obliged to face not only the problem of supplying sufficient oil, but the problem of simultaneously catering for " a major change in its trade." On this Mr. Hubbard points out that to-day, " while half the population of the world consumes less than one-twentieth of the *per capita* consumption of the U.S.A.," oil is already providing 37 per cent of the world's total energy requirements—or 50 per cent if natural gas is included. He thus deduces that " when the standard of living in the underdeveloped countries rises, the demands for energy will become enormous and eventually beyond the world's resources of fossil fuels (coal, oil and gas)." Nuclear energy is thus essential in the long run if the world is to progress.

From the point of view of the diesel engine user the crux of Mr. Hubbard's paper lies in those " Conclusions " wherein he sums up the problems confronting both the oil industry and the engine user. So far as concerns the oil industry, " the major problem. . . will be to produce sufficient middle distillates, notably diesel oil, if present trends continue." As a consequence, while Mr. Hubbard expressly states that (apart from world events and factors outside the control of the oil industry) " ample total supplies of oil are in sight for many decades to come," he recommends that " to ensure maximum supplies the specification of diesel fuel should be as little restrictive as possible. . . . The diesel engine, if it wants to be sure of an adequate food supply, must be omnivorous." This need not disturb us unduly if we remember how, as long ago as 1891—when there was no specification at all—the late Professor William Robinson suggested to Akroyd Stuart that he should heat palm oil in the vaporiser jacket of his engine, thus lowering its viscosity prior to injection into the combustion chamber. This suggestion was adopted by Akroyd Stuart and the tests thereafter made led, incidentally, to the development of his pilot injection system. It is further on record that at the Paris Exhibition in 1900 the Otto Company ran a small diesel engine on peanut (*Arachis Hypogaea*) oil, respecting which demonstration Rudolf Diesel, speaking in March, 1912, before the Institution of Mechanical Engineers, uttered the following courageous words which may be recalled with interest to-day: "If we consider that the diesel engine can utilise vegetable oils, entirely new prospects are brought to light for the cultivation and expansion of industry in the Colonies, which are for no other country of such eminent importance as for Great Britain. . . . The diesel engine can be worked with the Colonies' own resources, and thus again can influence to a great extent the further expansion of agriculture in districts where it is predominant. This sounds to-day somewhat like a dream, but the author ventures to prophesy, with full conviction, that this way of using the diesel engine will one day be of the utmost importance."

Dr. Diesel also remarked that while it might be impossible to predict what part such oils could play in future Colonial development, indications were such as to " make it certain that motor power can still be produced from the heat of the sun, which is always available for agricultural purposes, even when all out natural stores of solid and liquid fuels are exhausted." Since nuclear energy has now been added to other resources, there is no reason why we should turn pale at the possibility of renewed blocking of the Suez Canal, though it must be hoped that steps will be taken to prevent the recurrence of so insensate an act. Meanwhile, our engine designers and builders together with the manufacturing and research organisations which so effectually co-operate with them will certainly appreciate any authentic warning signals raised by the oil industry. Such warnings, taken seriously not tragically, are certain to have a tonic effect on all possessors of imagination, whether professional participators in industry or not. " Sweet are the uses of adversity " !

The Engineer
100 Years Ago
(JANUARY 23, 1857)

" A Rope's End "

" Amongst all the wonderful applications of science to the ordinary purposes of life which characterise the present century, the application of electricity to the purposes of telegraphing will, perhaps, stand out as the most prominent. Its importance to mankind cannot be over estimated. That men should be able practically to converse, and not only to converse, but to wrangle and blow each other up, when stationed two, three and no one knows how many more thousands of miles apart, is an achievement of science and art of which a few years since even poets did not dream approaching as nearly as they did to all that is possible and impossible with men.

" Great as our advance has been of late in all the various details of laying down wires, both subterranean and submarine, there yet appear to be many questions of considerable importance which have not, up to the present time, been satisfactorily solved. Amongst these may be named the velocity with which a current travels along a wire, it having been variously estimated by experimentalists at from one thousand to nearly two hundred thousand miles per second ; while there are some who consider that the time of transit along any length of wire is perfectly inappreciable. Now, to reconcile these opinions, if reconciliation be possible, it seems necessary to suppose that some tangible effect is produced at the both ends of the longest wire at one and the same time. This effect, if it takes place is, however, so feeble as to be perfectly useless in directly working any telegraph apparatus, and thus in the case of long lengths of wire it is necessary to work very deliberately, giving ample time for the propagation of the electric wave along it. Up to the present time little inconvenience has been experienced from want of speed in telegraphing from place to place, inasmuch as the distances of continuous wire through which messages have been sent have been of no very great lengths ; but the idea of uniting England with America very naturally called into question the circumstances necessary to attend to in attempting the transmission of messages along wires of nearly 2,000 miles in length. . . . In the carrying out of all the details of this gigantic operation much ingenuity will doubtless be required ; but we believe it is in the right hands to insure its successful accomplishment."

A Seven Day Journal

Institution of Mechanical Engineers' Awards

THE Council of the Institution of Mechanical Engineers has announced the award of the James Watt International Medal, 1957, to Dr. Ing. Walther Bauersfeld, of Zeiss-Werke, Germany. The award is made as a recognition of Dr. Bauersfeld's work as a scientist, inventor and successful organiser, particularly in the application of precision engineering in the field of optics. This gold medal was founded by the Institution to commemorate the bicentenary of the birth of James Watt on January 19, 1736. The first award was made in 1937 to the late Sir John Aspinall for his work on the development of the railway locomotive. An award is made every two years to an engineer of any nationality who is deemed worthy of the highest award that the Institution can bestow and a mechanical engineer can receive. Dr. Bauersfeld is arranging to come to London early in May to receive the medal at the Institution and to deliver a lecture bearing on his work. Another award announced by the Institution of Mechanical Engineers is that of the James Clayton prize. This prize has been awarded to Captain G. T. Smith-Clarke and to Dr. H. J. Gough. Captain Smith-Clarke's award is for the invention, design and development of equipment used in medical practice, including mechanical breathing apparatus described in his James Clayton lecture (THE ENGINEER, December 21 and 28, 1956), and also for the development of mechanism used in connection with astronomical telescopes. and for his services concerned with aero-engines and automobile engineering. Dr. Gough receives the award for his pioneer work and sustained research leading to invaluable contributions in the field of fatigue of metals.

The Benjamin Franklin Medal

LAST year, the Royal Society of Arts decided to found an award known as the Benjamin Franklin medal, which is to be made annually "to individuals who have attained early distinction, with promise of future achievement, in the promotion of arts, manufactures and commerce." The medal, incidentally, was established last year to commemorate the 250th anniversary of Benjamin Franklin's birth, and also the 200th anniversary of his election to membership of the Royal Society of Arts. This week it has been announced that, with the approval of H.R.H. The Duke of Edinburgh, the president of the Society, the first recipient of the medal is to be Dr. Frederic C. Williams, M.I.E.E., F.R.S., Professor of Electrical Engineering in the University of Manchester, "for his contributions to electrical engineering." Professor Williams has occupied the Chair of Electrical Engineering at Manchester since 1946. During recent years, he has been prominently associated with pioneering work on automatic electronic digital computers.

D.S.I.R. Grants for Graduate Students and Research Workers

FURTHER details of the revised arrangements for post-graduate studentships in science and technology are given in a booklet published this week by H.M. Stationery Office for the Department of Scientific and Industrial Research. An earlier announcement reviewing the present system of awards for post-graduate study in the United Kingdom, was recorded in our issue of November 9, 1956. During this year, provided sufficient candidates of a high enough standard are forthcoming, the D.S.I.R. will award about 700 research studentships and about 200 advanced course studentships, a new kind of award. These figures compare with about 400 new maintenance allowances, now known as research studentships, previously awarded annually by the D.S.I.R., and the 250 to 300 that will no longer be awarded by the Ministry of Education and local education authorities in England and Wales. The value of the studentships, depending on where they are held and whether the students are living with their parents, will in many cases be increased on October 1 next. The D.S.I.R. states that, in making its awards, it will continue its present practice, and will not take the income of the parents into account. Future applications for the research studentships must be made for a quota and not, as in the past, for students by name. The applications, which must be submitted by the head of each department within the university, college, or other institution in which the students will receive their training in research, should reach the D.S.I.R. on or before March 1, preceding the academic year for which they are required.

Inauguration of Work on Bradwell Nuclear Power Station

IN an informal ceremony on January 18, Lord Citrine, chairman of the Central Electricity Authority, inaugurated work on Bradwell nuclear power station by cutting the first sod on the site. Lord Citrine was welcomed on the site by Sir Claude Gibb, chairman of The Nuclear Power Plant Company, Ltd., which is building the station. Sir Claude recalled that Great Britain had changed from a coal-exporting to a coal-importing nation with quite disastrous results on her economy. The decision to go ahead with the development of nuclear power was taken about two years ago—long before the Calder Hall nuclear power station had shown the wisdom of that decision and long before the Suez situation had shown the dangers of over-reliance upon imported oil for those sections of industry which could use an alternative fuel. Speaking of the formation of The Nuclear Power Plant Company, Ltd., two years ago, to specialise in nuclear power stations, Sir Claude said that in any overseas contracts, use would be made of the manufacturing capacity of the country concerned but the basic design and the supervision of construction would be done by the company's team of experienced engineers and scientists. Lord Citrine said that the twelve nuclear power stations originally proposed in the February, 1955, White Paper would have had (by 1965) a total output capacity of between 1500MW and 2000MW, with a heat value equivalent to about 5,000,000 or 6,000,000 tons of coal, which would still leave the country short of the equivalent of about 3,000,000 or 4,000,000 tons of coal. Thanks to recent advances in design, it was possible to meet this deficit with reactors of greatly increased size and heat output: the guaranteed net electrical output of the Bradwell station would be 300MW, compared with the figure of 125MW envisaged for the first nuclear power stations of the original programme. There was little doubt that, in two or three years, it would be possible to design a 500MW nuclear power station. Emphasising the urgent need for more power to make Britain competitive, Lord Citrine recalled that although the C.E.A. and the South of Scotland Board commissioned a record amount of new plant, 1937MW in 1956, that was less than one-sixth of the total commissioned in the U.S.A. in 1955. With the need for more plant, it should be remembered that nuclear power was comparatively untried: ultimate success was certain but, asked Lord Citrine, "would it not be prudent to regard these earlier nuclear power stations as being additional to, and not in part replacement of, our full normal programme of conventional plant?"

North East Coast Institution of Engineers and Shipbuilders

ABOUT 500 members, their guests and their ladies attended the annual dinner of the North East Coast Institution of Engineers and Shipbuilders, which was held on Friday, January 18, at the Old Assembly Rooms, Newcastle upon Tyne, with the president, Mr. R. C. Thompson, in the chair. After the loyal toasts had been honoured, that of "The Institution" was proposed by Vice-Admiral J. P. L. Reid, the Third Sea Lord and Controller. He said he felt strongly his position as sponsor of the shipbuilding and ship repairing industry. and assured those present that the importance of adequate supplies of steel as a fundamental factor in the output of tonnage was well understood by the Admiralty. Vice-Admiral Reid went on to assert that our growing merchant fleet still required a proportion of warships for its protection. The president in his response also touched upon the troubles of the shipbuilding industry in the matter of its basic materials. Lieut.-Colonel T. Eustace Smith, a past-president and fellow, proposed the toast of "Our Guests," on whose behalf Sir Donald Anderson, the president of the Institute of Marine Engineers, replied.

Packaging Exhibition

THE Packaging Exhibition, which opened at Olympia, London, on Tuesday last, January 22, will be open daily until Friday, February 1. At this exhibition more than 200 firms are showing the latest forms of packaging materials and equipment for all classes of goods from perishable foodstuffs to engineering components. A considerable amount of study has been devoted to the subject of packing in recent years, and the equipment to be seen in operation at the exhibition gives an interesting insight to the high degree of mechanisation which has been achieved in what is now an important branch of industry. The plant now available provides a quick, economical and efficient means of weighing, filling, packing, wrapping and sealing containers and materials of many kinds which but a few years ago involved the use of much time and labour. Not only does this new automatic equipment enable considerable savings to be made in manpower, but, where necessary, it operates under completely hygienic conditions and reduces the space requirements in factories to a minimum. Packaging materials have also received much attention and are now available in many new forms using plastics to good effect.

Hydrodynamic Lubrication of Piston Rings and Commutator Brushes

By W. LEWICKI*

No. II—(*concluded from page 86, January 18*)

The centrally loaded mode of lubricated sliding has often in the past been confused with parallel sliding. In fact, it is convergent, but physically and analytically quite unlike the familiar type, where the load is deliberately offset to cause convergence. At the same time, the mechanism of friction and film-forming action is quite unlike parallel sliding. For one thing, its deviation from parallelism is quite small, the film ratio is, say, 1·02 as against 1 for the parallel mode. Considering that the film thickness is at most 0·001 of the span of the fluid wedge, the small deviation can hardly be expected to be detectable, even by such sensitive methods as, for instance, Newton's fringes. The analysis reveals, nevertheless, that the minute convergence is responsible for something like 100-fold increase in film thickness in comparison with the strictly parallel mode, and a similarly decreased friction. Because the convergence required to do this is so small, clearly, it can develop spontaneously even if the sliding part is held quite "rigidly," say, by elastic deformation of the surfaces between which the fluid is entrapped. It is found that the new mechanism of lubrication can be expressed by unexpectedly simple algebraic formulæ, making it easy to handle and apply the whole theory to practical ends.

IN this discussion only the square-faced slider is analysed, for the sake of brevity. Consider the geometrical scheme of Fig. 4, *ante*, where $\beta=\pi/2$. Putting (12) for H in (31), we have

$$\frac{h_0}{\beta b}=\frac{2[\alpha^2+2\alpha-\varepsilon(\alpha^2-1)]ln\alpha-(\alpha-1)[5\alpha+1-4\varepsilon(\alpha-1)]}{(\alpha-1)[2\varepsilon(\alpha-1)(\alpha-2)-\alpha^2+4\alpha+1]-2[2\alpha-\varepsilon(\alpha-1)]ln\alpha} \quad . \quad . \quad . \quad . \quad . \quad (39)$$

The arrangement of Fig. 4 represents one of the many possible ways of eliminating the variables β and ε by constructional means. By making β=constant, ε=constant, α becomes the only variable in (39). Such an expression could, in principle, be used to eliminate α from equation (12) to give the pressure distribution parameter H in terms of (h_0/b) alone, to eliminate H from A_1 by (23), and to express the load (22) and friction (37) in terms of (h_0/b). However, α in (39) cannot be expressed directly in terms of (h_0/b) and this procedure would lead to all the expressions having an infinite series of algebraic terms. A reversed procedure, where (h_0/b) is eliminated from all equations by α of (39), would overcome the difficulty of the infinite series but it no doubt would lead to obscuring the picture by long and unweildy algebraic expressions and by the (unwanted) presence of α. We have to resort, rather, to numerical methods of solution—say, by computing the numerical values of all the variables for a number of specific values of α. Cross-interpolation or cross-plotting can be used to eliminate α and to give all intermediate values.

It is perhaps worth noting in passing that the computation itself is made peculiarly difficult by (39), in a manner which is not at first sight apparent. Namely, the terms of (39) containing a logarithm are on the whole so nearly equal to the remaining (subtractive) terms that on some occasions it was found necessary to compute as many as thirty-three decimal places in natural logarithms in order to resolve the differences to, say, seven significant places. Since this was not connected with uncommonly strained conditions of loading, one gets the impression that perhaps (39) is, as it were, an algebraic corruption of a simpler physical law. As is shown below, this is indeed the case. Nevertheless, the matter is by no means fully understood as yet. Clearly, the occurrence of two important but nearly equal subtractive terms is not a mere mathematical peculiarity, but must have a profound physical meaning, e.g. for the understanding why the behaviour in sliding should be extremely sensitive to small distortions in the shape of the fluid wedge, such as by elastic deformations. Leaving a fuller discussion of this subject to a separate publication, we now briefly outline the case $\varepsilon=0\cdot5$, i.e. the case of the centrally loaded slider. Applying numerical and graphical methods of solution to (39) with $\varepsilon=0\cdot5$, unexpectedly, the following power relations were discovered :

$$\frac{h_0}{b}=c_1\left(\frac{\eta U}{N}\right)^{\frac{1}{3}}=c_2\mu^2 \quad . \quad . \quad . \quad . \quad (40)$$

$$\mu=c_3\left(\frac{\eta U}{N}\right)^{\frac{1}{3}}=c_4\left(\frac{h_0}{b}\right)^{\frac{1}{3}} \quad . \quad . \quad . \quad (41)$$

$$\alpha-1=c_5\left(\frac{\eta U}{N}\right)^{\frac{1}{3}}=c_6\mu \quad . \quad . \quad . \quad . \quad (42)$$

$$\gamma=c_7\left(\frac{\eta U}{N}\right)=c_8\mu^2 \quad . \quad . \quad . \quad . \quad (43)$$

Numerical values of the coefficients c_1 to c_8 are given in Table IX, against the value of α at which they were computed. The corresponding numerical values of the variables $N/\eta U$, b/h_0, μ, γ are included for reference. By combining the relations (40) to (43) twenty straight formulæ can be written down in all and their numerical coefficients can readily be worked out from the values given in the table. In order to indicate the degree of constancy for the coefficients c_1 to c_8, their ratio $(c_{\alpha=1\cdot1}/c_{\alpha=1\cdot01})$ is given in Table X. This table covers a nearly 1 : 1000 range in the non-dimensional load, $N/\eta U$. Given the size of the slider, the useful range of α would ordinarily be a small portion within the range $\alpha=1\cdot1$ to $1\cdot01$, for the size of the slider $b=0\cdot1$ to 10cm. It should be pointed out in this connection that so far we lack a clearly defined criterion as to what is to be regarded as a useful range of load or of the film thickness.

As is evident from Table IX, each coefficient tends to a limit value when $N\to\infty$. For instance, it is found that

$$N/\eta U\to\infty,\ c_1\to\sqrt[3]{\frac{10}{4\pi}}=0\cdot926680 \quad . \quad (44)$$

It would appear, therefore, that the true physical meaning of the first equation (40) really is

$$\left(\frac{\eta U}{N}\right)^2_{U\to0}=0\cdot4\pi\left(\frac{h_0}{b}\right)^3 \quad . \quad . \quad (45)$$

where the coefficient $0\cdot4\pi$ remains virtually constant throughout the useful range of sliding velocities, although, strictly speaking, it applies only to vanishingly small velocities. For the present purpose the first relation (40) is important, not so much because the coefficient c_1 happens to be least variable (see Table X), but mainly because it enables prediction of the film thickness at the design stage. The second relation (40) can be used to obtain an estimate of the film thickness from the measurement of the coefficient of friction μ. The first relation (41) can be used to predict friction at the design stage; otherwise it provides a useful check on (40). Namely, any deviation from Table IX in c_3 by measurement can be taken to be a measure of disturbances, such as an excessive surface roughness for the assigned load (if the measured value of μ is too large) or elastic deformations, &c. (if the measured value of μ is too small). Of course, this check is subject to the experimental results being themselves right. In particular, the film temperature and film viscosity ought to be known with certainty.

It may be interesting to note that the variation of the coefficients c_1 to c_8 seems to be genuine ; that is to say, not artificially caused by the one-dimensional "polar" approximation of this analysis. We have no complete answer to this point, but the clue to this effect is as follows :—The variation persists throughout the general solution of (39), and it is by no means confined to the case $\varepsilon=0\cdot5$. For instance, it is much the same in its magnitude with large convergencies (not now discussed), even over the range where Reynolds' theory is valid throughout. Of course, the "polar" one-dimensional approximation is not the only possible source of error. There is also Reynolds' one-dimensional orthogonal approximation and Navier's fundamental approximation. All these three sources put together could perhaps account for the variation ; it would certainly be a fascinating subject of study for

TABLE IX—*The case of the square-faced and centrally loaded slider, computed with the help of equation* (39). *The surfaces are assumed to be ideally smooth and not elastically or plastically deformed. The analysis refers to the steady state of sliding, that is to say, a prolonged run at a constant sliding velocity, constant load, constant film temperature, and an ample lubrication with no air bubbles or abrasive particles in the lubricant*

$\alpha=$	1·2	1·1	1·05	1·02	1·01	1·001
$N/\eta U=$	918	6,168	44,860	660,000	5,173,000	5,077,000,000
$b/h_0=$	104	367	1,369	8,197	32,310	3,188,000
$\mu=$	0·11	0·06	0·03	0·01	0·006	0·0006
$\gamma=$	$2\cdot10^{-3}$	$3\cdot10^{-4}$	$4\cdot10^{-5}$	$2\cdot10^{-6}$	$3\cdot10^{-7}$	$3\cdot10^{-10}$
$c_1=$	0·90659	0·91695	0·92192	0·92481	0·92575	0·92659
$c_2=$	0·86147	0·83983	0·82070	0·80645	0·80123	0·79633
$c_3=$	1·02586	1·04490	1·05987	1·07087	1·07490	1·07869
$c_4=$	1·07741	1·09120	1·10384	1·11356	1·11718	1·12319
$c_5=$	1·94372	1·83394	1·77662	1·74136	1·72946	1·71868
$c_6=$	1·89472	1·75513	1·67626	1·62612	1·60894	1·59330
$c_7=$	1·76216	1·68162	1·63793	1·61042	1·60104	1·59250
$c_8=$	1·63224	1·47409	1·37571	1·31138	1·28913	1·26879

TABLE X—*Ratio* $(c_{\alpha=1\cdot1}/c_{\alpha=1\cdot01})$ *for the numerical coefficient c in equations* (40) *to* (43)

c_1	c_2	c_3	c_4	c_5	c_6	c_7	c_8
0·991	1·048	0·972	0·977	1·060	1·091	1·050	1·143

* Department of Chemical Engineering, Imperial College of Science and Technology, London. The work described in this article has been done in association with the physics department, Birkbeck College.

someone theoretically minded. Note in this connection how small the inlet pressure is with the centrally loaded slider. We have, by (14),

$$\frac{p_i b}{N}=\frac{6}{\alpha\beta}\left(1-\frac{H}{2\alpha}\right)\left(\frac{h_0}{b}\right)\left(\frac{\eta U}{N}\right) \quad . \quad . \quad (46)$$

As is readily verified with the help of Table IX, for $\varepsilon=0\cdot5$ this amounts to

$$\frac{p_i b}{N}=c_9\left(\frac{\eta U}{N}\right)^{\frac{1}{2}} \quad . \quad . \quad . \quad . \quad . \quad . \quad (47)$$

The ratio $p_i b/N$ is the inlet pressure per unit of the mean pressure over the slider. Some values of (47) are given in Table XI. Evidently the inlet pressure is much too small to have a direct effect of any consequence on the film thickness, so that its role is virtually confined to the equilibrium magnitude of α (equation (33)). A further clarification of the mechanism of lubrication in the centrally loaded sliding is obtained from the numerical values of the pressure maximum, $p_m b/N$, included in Table XI, against the corresponding positions of the pressure maximum point. We have, by (15),

$$\frac{P_m b}{N}=\frac{3(H-1)^2}{(\alpha-1)H}\left(\frac{\eta U}{N}\right)\left(\frac{b}{h_0}\right)^2 \quad . \quad . \quad (48)$$

which is seen to be virtually constant as a whole. Note that for an elliptic pressure distribution there would be $p_m b/N=4/\pi=1\cdot2732$, and it would be $1\cdot5$ for the parabola. We conclude that the pressure distribution is in fact very nearly parabolic. The degree of symmetry can be inferred from the included values x_m/b by (17). Note how nearly these values approach the ideal $0\cdot5$. Finally, a word about the respective merits of the parallel and centrally loaded mode of sliding. As is seen from Table IX, while $U\to0$, $\alpha\to1$. That is to say, the slider tends to become parallel. One can easily guess that this is quite a different type of parallelism from the $\varepsilon=0\cdot333$ case (the truly parallel slider). Evidently the $\varepsilon=0\cdot5$ case would carry in the limit infinitely more load at a given film thickness or, vice-versa, give an infinitely thicker film at a given load. We have, by (24), (40), for $\beta=\pi/2$,

$$\frac{h_{0,\,\varepsilon=0\cdot5}}{h_{\varepsilon=0\cdot333}}=c_{10}\left(\frac{N}{\eta U}\right)^{\frac{1}{2}} \quad . \quad . \quad . \quad . \quad (49)$$

$$\frac{\mu_{\varepsilon=0\cdot5}}{\mu_{\varepsilon=0\cdot333}}=c_{11}\left(\frac{\eta U}{N}\right)^{\frac{1}{2}} \quad . \quad . \quad . \quad . \quad (50)$$

Some numerical values of the ratio $(h_{0,\,\varepsilon=0\cdot5}/h_{\varepsilon=0\cdot333})$ by (49) are given in Table XII. The reciprocals of (50) are virtually the same. Note that the difference between the cases $\varepsilon=0\cdot5$ and $0\cdot333$ is not merely of degree but of kind. However, as will be shown in later publications, the centrally loaded mode of sliding is equally different in kind from what is usually understood to be the convergent mode of sliding, i.e. when $\varepsilon>0\cdot5$.

TABLE XI—*Numerical values of the inlet pressure p_i and maximum pressure p_m computed from* (47) *and* (48) *with the help of Table IX. The position of the maximum pressure point x_m by* (17) *is counted from the narrower end of the fluid wedge*

$\alpha=$	1·2	1·1	1·05	1·02	1·01	1·001
$p_i b/N=$	0·1965	0·1081	0·0569	0·0235	0·0119	0·0012
$c_9=$	1·9098	1·9820	2·0206	2·0446	2·0528	2·0601
$p_m b/N=$	1·4482	1·4722	1·4856	1·4941	1·4970	1·4997
$x_m/b=$	0·4727	0·4858	0·4927	0·4970	0·4985	0·4999

$\alpha=$	1·2	1·1	1·05	1·02	1·01	1·001
$c_{10}=$	0·9522	0·9610	0·9657	0·9685	0·9695	0·9703
$c_{11}=$	0·9856	0·9995	1·0126	1·0227	1·0265	1·0301

TABLE XII—*The ratio $(h_{0,\,\varepsilon=0\cdot5}/h_{\varepsilon=0\cdot333})$ by* (49), *giving the proportionate increase of the minimum film thickness in the square-faced centrally loaded slider in comparison with the truly parallel slider. The friction by* (50) *is decreased in just about the same proportion*

$N/\eta U=$	10^3	10^4	10^5	10^6	10^7	10^8
	10	21	45	97	209	450

Conclusions

Over and above the experimental work described in the article on the parallel mode of sliding only little has been done with due regard to the present theory in the way of direct observations on the pattern of velocities within the inflow region of flow. An outstanding finding by the present writer was that the pattern remains virtually the same whether the mode of sliding is parallel, convergent or divergent. This has been observed in the fluid bath experiments as well as with the help of the ingenious Rayleigh's device of thin elastic plates. The latter method was found to be particularly informative. For instance, it has given the hint that the one-dimensional polar approximation of the present paper applies not only to the two-dimensional viscous flow, but also to the theory of flexure of thin elastic plates and, presumably, to all sorts of two-dimensional problems of electrostatics, heat transfer, diffusion, electroplating, &c.

The whole analysis so far, including the parallel mode of sliding, describes only the steady state. It is the end state of an experiment at a constant value of the non-dimensional load $N/\eta U$, after a sufficiently long time has elapsed from the beginning of the run to allow the film thickness to settle down to its theoretical value. For example, if the theoretical film thickness is less than, say, $h_0/b=10^{-4}$ while the experiment is started with a much thicker film, it seems that on some occasions the process of leaking out would take hours or even days, in spite of the movement. Incidentally, it is perhaps not generally appreciated that in order to keep the factor $N/\eta U$ constant it is not enough to have a constant-temperature bath of liquid in which the slider moves at the constant velocity U under a constant load N. The temperature of the body of the slider itself and that of the supporting plane must also have reached its steady-state value beforehand. Otherwise the film viscosity would vary with time and make the true value of $N/\eta U$ different from what it is supposed to be. In point of fact it appears that the temperature of the fluid bath in itself is quite irrelevant to the film viscosity. The reason for this apparent anomaly is, of course, that the contact between the fluid within the film and the surfaces is so intimate that the fluid acquires the temperature of the surfaces almost at once on entering the film, whatever the bath temperature. One other point is that the velocity U must not be of the stick-slip kind, but quite steady for the purpose of the present theory. When the slider makes its progress in a jerky fashion it is not only U that varies, but evidently also the load N violently fluctuates. This is a typical case of elastic vibration of the system as a whole. The friction and the film thickness cannot be expected to obey the same laws as in the steady mode of sliding, but for all that the mechanism of lubrication need not cease to be hydrodynamic.

If the sliding velocity varies widely but smoothly, as in the case of piston rings in the conventional reciprocating engine, the problem how the film thickness h_0 varies along the stroke must await a study on the lines suggested above. However, as a matter of a rather loose approximation, the mean velocity of sliding can be taken for U and the time-mean pressure load per unit length of the circumference plus the prestress load per unit length can be taken for N. Inserting these values into (40) the resulting film thickness h_0 should not be far removed from the true time average value. The least thickness h_0, at or just after the top dead centre, would presumably be somewhat less than the value thus calculated. Incidentally, note that if we put $P=N/b$ into (40), we obtain

$$h_0=0\cdot925b^{\frac{1}{2}}\left(\frac{\eta U}{P}\right)^{\frac{1}{2}} \quad . \quad . \quad . \quad . \quad (51)$$

Evidently in the pressure-loaded slider the size of its width b has only a small effect on the value of the minimum film thickness in comparison with the previously discussed case where the unitary load N does not vary with b. Note particularly that N is not the overall load. We can put $N=W/a$, where W is the total load and a is the length of the slider crosswise to its motion. It would appear from (51) that, as far as the effectiveness of lubrication is concerned, there is no strong objection against very narrow piston rings. However, this suggestion cannot be upheld very strongly until we know more about the respective merits of h_0 and h_0/b as a possible criterion for predicting the critical value of load above which an excessive surface wear would take place in any given conditions of operation.

Strictly speaking, the steady state theory of centrally loaded sliding in its present form applies only to the infinitely long slider, i.e. where there are no appreciable end losses. It seems, however, that it can be used as a fairly good approximation to various parts of machinery, where the load is not deliberately offset to cause convergence or parallelism and where the part can be said to "sit" after the period of running-in. That is to say, after adjusting itself to be apparently quite parallel as a result of slight initial wear. When the fundamental cases of geometrically simple shapes for the underface of the slider (circle, square, triangle) are computed we shall know more about the errors caused by using the present analysis to cases with an obvious end flow. Evidently, the film thickness is always somewhat reduced by the side leakage from under the slider. In the present author's view, however, this sort of error on the estimate of the film thickness or the coefficient of friction is, as a rule, trifling in comparison with the errors incurred by neglecting the local changes in film viscosity by heat and pressure, on the one hand, and by neglecting the changes in the hydrodynamic flow caused either by elastic deformations of the overall shape of the surfaces between which the flow occurs or by more or less permanent unevenness like the surface asperities or permanent deviations from the assumed geometrical shape like, for instance, chamfered edges. A short discussion on the effect of elastic deformations caused by the unevenly distributed pressure in the fluid layer under the slider on the behaviour of a rigidly held and apparently

parallel twin sliding pad has already been published.§

Presently consider some numerical examples of the film thickness by (40) or (51). For a piston ring $b=3\cdot2$mm ($\frac{1}{8}$in) without chamfer at, say, $\eta=0\cdot1$ poise, $U=10$ m/s, $P=3$kg/cm^2, we obtain $h_0=0\cdot00066$cm or $0\cdot00026$in. If these P and U are averages, according to the remarks preceding equation (51) the computed h_0 approximates its true average value. Because of the delaying action of the viscous flowing in and out under variable conditions it can be expected that the least and greatest values of h_0 depart only a little from the average. The fluid film seems to be exceedingly thin in ordinary sense, but on the molecular scale of dimensions this represents the enormous thickness of 66,000 Angstroms. By widening the ring to 1in we only increase the film to twice the amount and by narrowing it to $^1/_{64}$in we only halve the film thickness. We now turn to the field of commutator brushes in an electric machine. For a carbon compound element 1cm square over 10cm diameter of the track at 3000 r.p.m. and at $P=50$gr/cm^2, $\eta=0\cdot02$ centipoise (the air at atmospheric pressure), we find $h_0=0\cdot00032$cm or $0\cdot00013$in. To take another example, a copper wire element whose individual strands are $0\cdot2$mm square and act as individual sliders: with η and U as before and at $P=100$gr/cm^2 there results $h_0=0\cdot000054$cm or $0\cdot000021$in. On the molecular scale this is still a considerable thickness of 5400 Angstroms. Adding to this the usual contaminating films of grease and moisture, it seems that the true separation in the above conditions would be several times the amount. It would still be too thin to be observed or measured by ordinary means.

It is fortunate to have an analytic proof that solids when rubbed together under load should remain separated by a substantial film of liquid or gas. This view could never be adopted in the past, probably because of the theory originated by Reynolds (1886), from which it appeared that it is quite easy to scrape off all fluid by rubbing two bodies together. The many common indications to the contrary were, on those mistaken mathematical grounds, explained away by various devices. We now have some evidence to show, surprisingly enough, that even under such strenuous conditions that the wide-spread surface failure becomes imminent there still is a substantial film in between. Were it definitely known that it is so this would mean that it is not the film which fails first, but the surfaces, say, by melting away. How would then the film disappear ? Say by going into solution with the melt under the pressure which may be extremely high locally. It is perhaps appropriate to recall in this connection that, in the writer's view, the "anti-friction" additives to lubricants act mechanically or chemically and not by virtue of the oriented molecular fields of the classical hypothesis. If it is a solid additive—say, the minute plates of graphite—it would (1) increase the effective viscosity of the film by subdividing it mechanically into numerous compartments and sub-layers and (2), its deposition on the surfaces would tend to fill the gaps between the individual asperities, making the surfaces smoother and capable of operating a thinner film, i.e. heavier load. The chemical action would, according to this interpretation, concern itself with the destruction of the abrasive metallic oxide debris. If the chemical nature of the additive is such that the metallic surfaces are only attacked mildly its action on the detached debris on all sides should be much more when they just happen to be caught in the act of ploughing (when held between the peaks effective due to their minute size, particularly of the opposed surface) or in the act of denting and cracking the protective oxide film of both the surfaces at a time (when rolling in the manner of a small toothed wheel in its two-sided geared attitude). The reason why the debris should then become particularly vulnerable themselves is, of course, because then they become hot. Having corroded away the debris the active agent next attacks these of the peaks of the asperities which happen to be coming too close to their opposite numbers and become hot through the intense fluid shearing in the fluid surrounding them or through plastic deformation from the intense local fluid pressure. The preferential degradation of the peaks should then result in the formation of numerous minute plateaux, each acting as a centrally loaded slider. Provided that some chemical agent still remains, to keep a watchful eye on any newly born debris and destroy them before much new harm is done to the plateaux, a high load-carrying capacity and no further wear could perhaps be made to last indefinitely. Incidentally, a purely thermal (molecular melting) action could perhaps be substituted for the chemical one in order to develop the desirable plateaux, in the manner of what seems to be happening in the course of optical polishing.

Different lubricants, as well as different materials of which the sliding surfaces are made, are well known to give, on the whole, different friction under the same conditions of loading. Within the present interpretation the cause would mainly be the differences in the shape and size of the fine-surfaced asperities. That is to say, provided that the load is sufficiently heavy to force the surfaces closely enough for the individual asperities to disturb the flow in the remaining bulk of the film. However, a similar behaviour is also known to occur in the region of lighter loads, where the bulk thickness of the film becomes too large for the asperities to play any role. One is inclined to conclude that the friction is then affected by elastic characteristics. Different materials on the whole deflect differently under the same load. The shape of the fluid wedge thus varies from material to material. The foregoing analysis seems to provide a good example how the apparently minute changes in the shape can lead to quite drastic differences in the film thickness and friction.

§ W. Lewicki, THE ENGINEER, May 11, 1956, pages 486-487.

New Tower Clock at Malmesbury Abbey Church

By T. R. ROBINSON, F.B.H.I.

The new automatically-wound tower clock, now at work in the detached bell-tower of Malmesbury Abbey, Wiltshire, is a particularly interesting example of modern horological engineering, for its mechanism embodies some distinctly novel points of design, exemplifying the flexibility of the modern electrically operated tower clock.

THE new timekeeper in the detached bell-tower of Malmesbury Abbey, Wiltshire, designed to replace the old-fashioned "birdcage-frame" clock that had been in service for about one hundred years, is made up of three distinct units. Although this clock is sufficiently compact to be located in the ringing-room of the tower without encroaching on the space required by the bell-ringers, it is much more powerful than its predecessor, and requires far less attention.

When the old clock was first installed, it was placed in the ringing-room, but, as its presence there made ringing very difficult, it was later removed to the foot of the tower. This entailed the provision of an extremely long leading-off rod to transmit the drive to the hands of the dials, which are near the top of the tower, and this, in turn, made the time shown unreliable because of the torsion and backlash in the rod and its various couplings and joints.

The recently completed re-tuning and re-hanging of the bells prompted suggestions that the old clock should be replaced by one better able to keep precise and reliable time, and that the improvement in the tune of the bells warranted more ambitious quarter chimes than the old "ting-tang" quarters formerly used. The decision was made to install an electrically operated Westminster chiming clock of modern design that would obviate the need for hand-winding. It was also decided that, as the possibility of variations and interruptions of the current in the a.c. supply mains renders a synchronous-motor driven clock liable to irregularities and stoppages, an automatically-wound type of timepiece, linked to motor-driven striking and chiming mechanisms, would be the best form of clock to install.

The clock was constructed by John Smith and Sons, of Derby, and its general lines follow the "unit" design which has been adopted by this firm, coupled with some ingenious modifications to suit the needs of this particular installation. In this form of construction, each section of the clock mechanism, such as the timepiece, chiming part, and striking part, has its own separate bedplate, the layout of which is so arranged that each unit can be matched up with others to operate in the most convenient way. Units can either be grouped together, or placed in any suitable position. This form of design is often of considerable value where space is limited, and it proved particularly helpful at Malmesbury, for it enabled the chiming and striking units to be located at a point some distance from the timepiece, and well clear of bell-ropes and other fittings.

The timepiece section of the Malmesbury clock shown in Figs. 1 and 2, is constructed on lines that are rather a departure from accepted tower clock practice, for the train, though consisting of wheels and pinions of the normal form, is housed in a small sub-frame of the "pillar-and-plate" type, instead of being carried by a number of bars and brackets attached to the main frame casting. The driving weight is suspended from an endless length of roller chain in the usual "auto-wound" manner, the winding being carried out by a fractional horse-power motor and reduction gear, which operates without affecting the action of the rest of the timepiece.

The escapement is of the "double three-legged gravity" form, in which two weighted

arms are raised in turn by the escape wheel, and deliver gravitational impulses to the pendulum as they descend. This method of impelling the pendulum obviates variations in timekeeping arising from wind pressure on the clock hands, and other adverse weather conditions. To compensate the

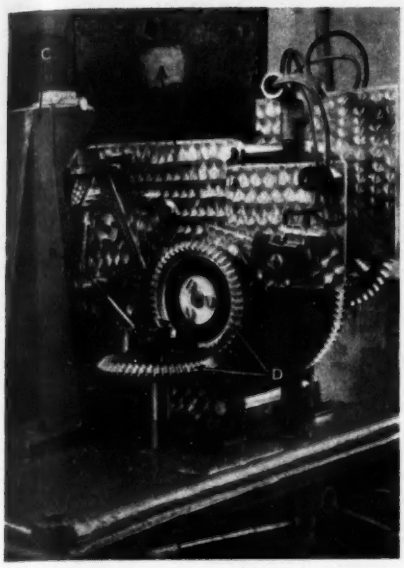


Fig. 1—Timepiece unit, showing gravity escapement, pendulum suspension bracket, bevel gears driving dials and let-off switch assembly

pendulum against temperature errors, it is fitted with an Invar rod.

Mounted on the large rectangular cast-iron bedplate of the timepiece are the frame containing the train and escapement, the pendulum suspension bracket, the first section of the leading-off work, the motor and reduction gear for winding, and the various switchgears necessary for winding, letting off the chiming and striking, and silencing the clock at night. All the components are well spaced, and there is ample room for maintenance and adjustment.

The frame *A* containing the wheels and pinions of the timepiece train is really an enlarged version of the familiar form used

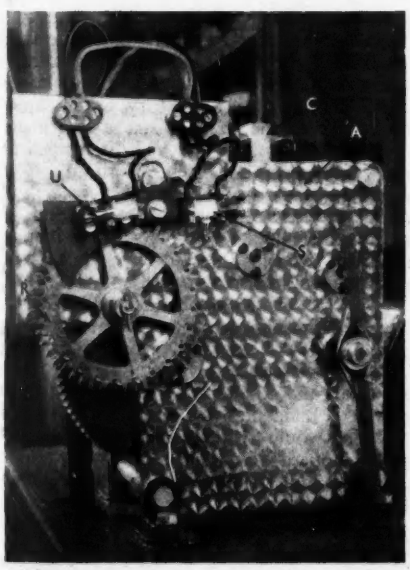


Fig. 2—Rear view of timepiece train frame showing twenty-four-hour wheel and two mercury tube switches

for domestic clocks, the two rectangular frame plates being spaced and united by four stout pillars. The pivots of the various spindles of the train do not take their bearings directly in the plates, but are all provided with removable flanged bushes fastened to the plates by screws. This permits each pivot to be cleaned and inspected without dismantling the frames, but, in addition, the whole frame assembly can be easily removed from the bedplate if necessary without disturbing any of the other components.

The gravity escapement, *B*, differs considerably from the usual form in its arrangement, for the double three-legged escape wheel is mounted on the projecting end of the suitably lengthened front pivot of the final, or "escape" spindle, whilst the "fly" or air brake is mounted on the end of the lengthened back pivot, to which it is coupled by a small friction clutch. The two gravity arms which drive the pendulum are fitted to the top of the front frame plate, pivoting between it and a small additional bridge carried by two short pillars. This construction renders the whole escapement assembly both neat and rigid. A small release-lever is provided behind the upper ends of the gravity arms, and by lifting this, both the arms can be raised clear of the escape wheel when it is necessary to advance the escapement to make a correction for a losing error, or to alter the clock for Summer Time. The correction for a gaining error, or for the reversion to Greenwich Mean Time, is quite simply made by stopping the escape wheel for the appropriate length of time.

The pendulum and its suspension bracket form a separate and self-contained assembly, whose only connection with the escapement is that the bracket is so placed that the pendulum rod hangs between the pins at the lower ends of the gravity arms, and in the right position to unlock them, and to receive its impulses from them. The suspension bracket *C* is a heavy A-shaped casting, bolted directly to the bedplate and carrying the upper anchorage blocks of the pendulum suspension spring by a steel pin that rests in grooves in two lugs at the top of the bracket.

The pendulum bob is a cylindrical iron casting, weighing 1 cwt, which rests on a large milled rating nut that can be turned to give adjustment of timekeeping in the usual way. The location of the pendulum near to the front of the movement makes regulation easy, and the final, very precise, timing of the clock can be made by placing small weights on the top of the bob.

The drive to the hands of the external dials is taken direct from the main wheel of the timekeeping train by a pair of bevel-wheels *D*, the driver being mounted on the extended front pivot of the main wheel spindle, and the driven wheel on a pedestal bearing on the main base plate. This driven wheel is coupled through a universal joint to the vertical shaft leading up to the further bevel-wheels at dial level.

The starting up of the chiming and striking units is operated from the first bevel-wheel on the timepiece by four "let-off" pins, which are fitted to the rear side of the wheel, and engage in turn with a switching, or "discharging," lever as the wheel rotates. The operation of the rest of the release mechanism of the clock is very novel and is dealt with below. The "setting dial," by which the clock is set to time, is fitted to the front of the first bevel-wheel, and takes the form of a circular plate, the circumference of which is marked with sixty minute divisions that are read against a pointer fixed to the front plate of the train frame.

The automatic winding mechanism of the timekeeping assembly is very simple and compact. One loop of the endless length of roller chain by which the weight drives the clock engages with a large-diameter sprocket, fixed close alongside the main wheel on the main spindle of the timekeeping train. On the driving side of this sprocket the chain hangs down and passes round a deeply-grooved pulley from which the driving weight is hung. Beyond this pulley the chain passes upwards again to engage with the winding sprocket on the final spindle of the winding unit. After passing over this the rest of the chain forms a large free loop, and so returns to its point of engagement with the large sprocket on the main spindle of the timekeeping train. With this endless chain arrangement the raising of the driving weight during rewinding does not cause any interruption of the drive to the timekeeping part of the clock.

The winding unit consists of a ¼ h.p. B.T.H. induction motor, coupled to a totally enclosed Opperman reduction gear. It is bolted to the bedplate alongside the timekeeping mechanism in a position which brings its winding sprocket into line with the sprocket on the main wheel spindle of the timekeeping train. The switchgear controlling the operation of the winding motor is actuated by the fall and rise of the driving weight iself. Fitted beside the winding sprocket on the final

Fig. 3—Rear view of timepiece unit, showing train frame, driving weight and switchgear assembly

spindle of the reduction gear is a second, or "switching," sprocket *E* (Fig. 3) that is free to rotate on the spindle, which merely serves it as a pivot pin. Engaging with the teeth of this switching sprocket is a short length of roller chain, the ends of which hang down on either side of the sprocket. One end of the chain hangs over the top of the clock driving weight, whilst the other end hangs free of obstruction. A small weight is suspended from each end of the chain, that on the end which hangs over the clock weight being considerably heavier than the one on the opposite end. This heavier weight normally rests on the top of the clock weight and falls with it as it descends, thus drawing its end of the chain downwards and rotating the switching sprocket. After this action has proceeded for a certain distance a pin *F* set in the side of the sprocket engages with a tongue on a rocker arm *G* and rocks the arm over.

The mercury switch controlling the winding

motor circuit is attached to the rocker arm, so that its movement switches on the motor and starts the winding of the clock weight. The raising of the clock weight also lifts the heavier of the switching weights and so enables the lighter weight to descend, rotating the sprocket in the opposite direction and moving the pin back round its circular path. The pin comes into engagement with the other side of the tongue on the rocker arm and rocks the arm back to break the motor circuit and stop the winding action. The whole cycle of operations is then repeated.

The winding is set to take place at approximately hourly intervals, but the length of roller chain on which the clock weight is suspended is considerably longer than is necessary for this period. This extra length of chain provides a " reserve " run, which enables the clock to continue running for about two hours if the current supply to the winding motor should have failed at the time when winding should take place. The clock is thus unaffected by failures of current in the supply mains unless they are of unusually long duration. If such a failure does take place the clock weight descends below its normal " lowest " point and leaves the heavier of the switching weights behind, picking it up again when the restoration of the current enables winding to be resumed. As a precaution against damage from overwinding, such as might occur if the winding switch failed to break the motor circuit when the weight was fully wound, a safety trip switch is fitted immediately above the clock weight. This breaks the winding motor circuit if the weight is overwound more than two inches above the normal fully wound point. Once this safety switch has been operated it must be reset by hand, and the need for this to be done gives warning that the winding switch has developed a defect.

The chiming and striking units of the clock are located some distance away from the timekeeping part. The chiming unit (Fig. 4)

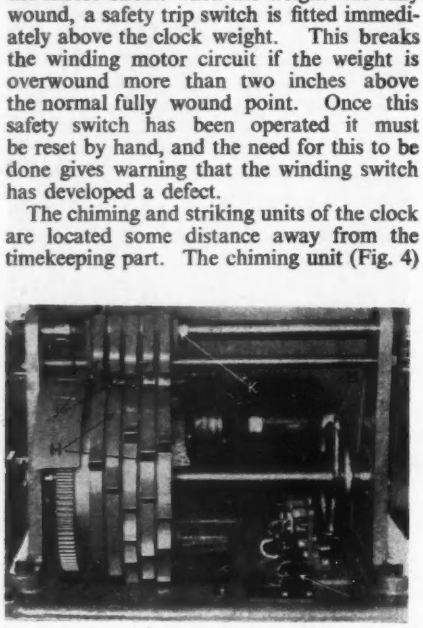


Fig. 4—Detail view of chiming unit, showing chiming cam barrel, pull-off lever, solenoid controlled switch and count-wheel

is driven by a ¼ h.p. motor and reduction gear identical with that used for winding the timepiece, the drive from the final spindle of the reduction gear being transmitted to the chiming cam barrel by two additional stages of wheel and pinion gearing.

The chiming cam barrel *H* is built up with the cams for each individual hammer cast in rings, and the whole assembly bolted to the side of the large gear wheel by which the barrel is driven. Although the Westminster or (to give them their correct title) the Cambridge chimes are sounded on four bells, there are five sets of cams, the additional set being provided to deal with the quick repetition of the lowest note that takes place during the third and fourth quarters.

The levers *J*, by which the chiming hammers on the bells are lifted, all pivot on one spindle, which also carries the pull-off lever *K* used to raise the whole group of hammers clear of their bells during change ringing. There are, of course, five hammer levers, the fifth being acted upon by the additional ring of cams on the cam barrel and raising an extra hammer fitted to the largest quarter bell.

The placing of the chiming and striking units at some distance from the timepiece assembly made it inconvenient to use the normal design of mechanical let-off for starting up the chiming unit, and so electrical mechanism is used. On the timepiece the usual let-off detent is replaced by a lever and trigger catch which control the operation of a small rocker arm that shares the same pivot pin as the lever and carries a mercury switch.

As one of the let-off pins on the back of the first bevel-wheel lifts the free end of the lever the trigger catch is set and, at the same time, the mercury switch is rocked to its " on " position. This closes a circuit energising the coil of a solenoid *L* forming part of the let-off mechanism on the chiming unit. The solenoid then sets a latch attached to the mercury switch controlling the motor driving the chime unit. This action does not start the motor, but presets the switch in readiness for starting.

As soon as the let-off pin on the timepiece releases the lever and allows it to fall the trigger catch on the lever trips the rocker arm and returns the mercury switch on it to its " off " position. The solenoid is then de-energised and its armature returns to its original position under the pull of a light return spring. As it does so it rocks the chiming unit motor switch and starts up the motor.

The quarter is then chimed, and when the correct sequence of notes has been sounded a pin on a " count wheel " depresses a small lever which trips the mercury switch back to its " off " position and stops the motor. The count wheel *M*, mounted on the same spindle as the chiming cam barrel, is provided with pins in the side of its rim near to the circumference. These pins are spaced to trip the motor switch to its " off " position at the correct instants for the first, second, third, and fourth quarters. The chiming unit therefore only needs to be started up by the timepiece and will then switch itself off automatically when the appropriate quarter has been chimed.

The count wheel also controls the letting off of the hour striking unit by means of an additional pin set in the opposite side of its rim. This pin engages with a lever linked to the switch mechanism of the striking unit and so presets and releases the switch mechanically in much the same way that the timepiece lets off the chiming unit switch electrically.

In many details, the striking unit (Fig. 5) is very similar to the chiming unit. It is also driven by a ¼ h.p. motor and reduction gear, but the final spindle of this reduction gear carries a single snail-cam *N*, which engages with and depresses the striking hammer lever *O*, once on each revolution of the spindle. Beside this striking cam is another, smaller cam, which propels the striking count wheel that governs the number of blows struck. This count wheel *P*, which is pivoted on a bracket beside the mercury switch controlling the striking unit motor, has seventy-eight teeth, and is fitted with a series of pins spaced to control the striking of the hours from one to twelve. Pivoted beside the wheel on the same pivot-pin is a lever *Q*, carrying a small spring-loaded pawl, and as the remote end of the lever is raised and lowered by the small cam on the final spindle of the reduction gear, the count wheel is stepped, tooth by tooth, being advanced one tooth for each blow struck on the hour bell, and locked against return

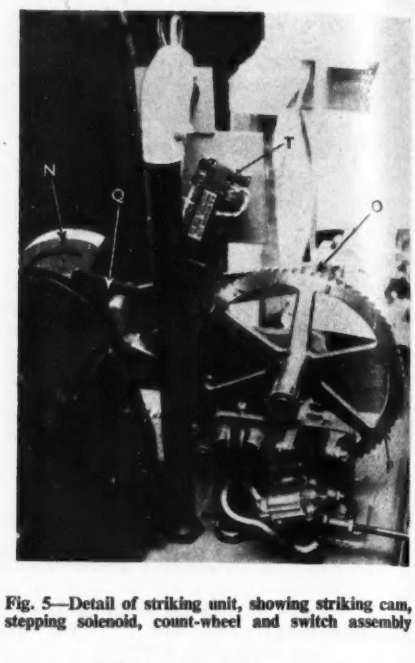


Fig. 5—Detail of striking unit, showing striking cam, stepping solenoid, count-wheel and switch assembly

by a small backstop pawl mounted on the bracket. When the correct number of blows has been struck, the appropriate pin on the countwheel trips the motor switch, and striking ceases until the next hour.

The most remarkable feature of the whole clock is its night silencing mechanism. Both chiming and striking are silenced from 10.45 p.m. to 7 a.m., to prevent annoyance during the night hours to those living near the bell tower. So far as the chimes are concerned, this does not present any special difficulty, for it is only necessary to interrupt the circuit between the mercury switch on the let-off lever on the timepiece and the solenoid *L*, operating the motor switch on the chiming unit just after 10.45 p.m., and to re-establish it just after 6.45 a.m. As the striking unit is let-off by the count wheel on the chiming unit, this action also stops the striking.

A 24-hour wheel, *R* (Fig. 2), of the type often used for such night silencing attachments, controls the switching of this let-off circuit by means of a mercury switch, *S*, so mounted on a rocking arm that it is normally in its " on " position, but can be tripped to its " off " position by the 24-hour wheel when the clock is to be silenced. The 24-hour wheel has forty-eight teeth, and is rotated once in 24 hours by the gathering action of two pins inserted in the end of the rear pivot of the main wheel spindle.

The 24-hour wheel operates its switching lever by pins screwed into several of a ring of twenty-four holes in the rim of the wheel. The pins are grouped to raise the lever at the set time, and to hold it up for the desired period. Incidentally, the removal of all the pins would render the silencing attachment inoperative, and so leave the clock chiming and striking during the night if this is ever required.

The silencing action of the 24-hour wheel is, however, not its only duty, for it has also been adapted to overcome the special problem of the adjustment of the count wheel on the striking unit. It will be under-

stood that the silencing of the chimes from 10.45 p.m. until 7 a.m. does not upset the proper sequence of chiming, for the fourth quarter still follows the third, despite the intervention of the silent period.

With the striking mechanism, matters are very different, for, as striking ceases at 10 p.m., and does not resume until 7 a.m., the countwheel *P* will not be stepped forward by the normal cam-and-lever action during the intervening nine hours, and so will be in the wrong position to count the striking of the necessary seven blows at 7 a.m. unless some other means of correction is applied. The method adopted is to continue to use the same advancing lever *O* and pawl that are normally operated by the small cam beside the main striking cam, but to lift and lower the lever during the "silent" hours by means of a solenoid *T* similar to that used for the let-off of the chiming unit. The solenoid action is also arranged to lift the lever higher than the cam does, and so to propel the countwheel forward two teeth each time it is lifted instead of only one. The novelty of the mechanism is that the necessary pulses of current that repeatedly energise the solenoid, and so obtain this stepping action, are obtained from the mercury switch on the timepiece that normally lets-off the chiming unit.

It will be remembered that the 24-hour wheel breaks the circuit between the let-off switch and the solenoid on the chiming unit just after 10.45 p.m. by tripping a mercury switch. Linked to this switch is another, *U*, so arranged that it completes its circuit when the silencing switch "breaks," but is also capable of breaking its own circuit independently of the restoration of the silencing switch. The two switches are interconnected electrically in such a way that when the silencing switch breaks the circuit between the timepiece let-off and the chiming unit, and the other switch completes its circuit, the effect is to divert the pulses of current normally used to let-off the chiming unit to the count wheel stepping solenoid on the striking unit. In this way, the let-off switch becomes the contact maker for the stepping solenoid, and causes the latter to advance the striking count wheel two teeth every time the let-off switch makes and breaks its circuit at 15 minute intervals.

The correction necessary to bring the count wheel to the right position for the resumption of striking at 7 a.m, requires it to be advanced forty-four teeth. As the solenoid action steps the wheel forward two teeth each time it operates, this advance is completed in twenty-two quarter hours. By this time, the timepiece will have reached 4.15 a.m., and after this "4.15" let-off has taken place, the 24-hour wheel releases the second mercury switch *U*, allowing it to return to its "off" position, and so to break the circuit between the let-off switch on the timepiece and the stepping solenoid on the striking unit. From then until the silencing switch restores the normal let-off circuit to the chiming unit just before 7 a.m., the timepiece let-off switch operates idly.

The "motion-works," or 12 to 1 ratio gears behind the dials that give the motion to the hour hands, were all renewed, as were the bevel gears and spindles leading from the clock to the dial centres. The hands were also renewed, the design chosen being one that enables the time to be clearly read from a considerable distance. The old dial plates which were retained were reconditioned. Since its installation, the clock has behaved extremely well, and after the necessary adjustment and regulation was completed, has proved itself an excellent timekeeper.

On Trade Disputes

(Contributed)

THERE must be many observers both within and without the Trade Union movement who feel that a stage in its history has now been reached wherein the collective wisdom of its constituents may be subjected to a severe test. It would surely be a calamity for the Trade Union movement if it failed to maintain its high status as an active and influential partner in a national team united in the effort to preserve, and indeed to promote, the life and well-being of the nation. This obligation rests, of course, on *all* the partners in the team, and upon their cohesion and sense of responsibility depend the welfare and even the continued existence of the country to which they all belong. There are no written rules for the guidance of this team since under our system of government the liberty of the individual—so long as he abides by the law of the land—is unfettered. In such circumstances the ultimate success or failure of the team is determined by the wisdom of its members.

No team will prosper if its members (or any one of them) are not set on playing the game and the game cannot be played unless the players (all of them) are able to see the direction in which the ball must be kicked. Otherwise, they can be making the pitiful mistake of attacking their own goal. At the present time the need for cohesion in the team is truly vital and this cohesion can only be achieved where there is such an understanding of the facts as will convince all players that no one is being imposed upon. Since human nature is fundamentally the same throughout the population of these islands and as the sense of what is a fair thing has long been regarded as primordial in the British character, we should all recognise that we have a duty not only to ourselves but to our posterity. If the damage wrought by any foolish procedures could be borne only by those responsible for them, the case would not be so bad. The fact is, however, that industrial folly now will, if protracted, bring privation and suffering on innocent posterity. Surely it is accepted that there can be no such thing as welfare without effort, and that at the present time the efforts of other nations render imperative the continuance or even the intensification of our own. This does not mean that there should be a state of planned and unremitting toil. It does mean, however, that there shall be an end to national damage caused by industrial irrationality from whatever direction it may come. We would regard it as the chief duty of Trade Union leaders to work for the long-term security of their members. They have in this a great and growing responsibility, moreover, they are able to make a signal contribution to the credit and reputation of the country. Never has there been a time when we had more need for wise and temperate heads among the Trade Union leaders and that such men are available and will be forthcoming we cannot doubt. We also look for the highest wisdom on the part of managements and for the realisation, by both sides in industry, that unless the credit and good name of the country can be maintained, the end must be calamity for all.

The first requisite is the establishment of mutual trust, and in this connection we agree with the recent utterance of a prominent American manufacturer who remarked how "More honest, intelligent and patriotic consideration of the welfare of the nation as a whole by the leadership of the various segments of our national life would seem to be more appropriate payment for the 'right to life, liberty and the pursuit of happiness' they have enjoyed under our constitutional system of human association." There is, in industrial discussions, a lamentable tendency to vituperative exchanges, and to the creation of a climate of conflict. What is wanted is a climate of *confidence*. Nothing is more conducive to confidence than good humour. This was strongly urged, a century and a half ago, by Thomas Jefferson, who had great experience of contentions disruptive of peace and tranquility. Where there might be a lack of natural good humour, he counselled *politeness*. "In truth," he remarked, "politeness is artificial good humour, it covers the natural want of it, and ends by rendering habitual a substitute nearly equivalent to the real virtue." Let us by all means cultivate in industrial relations the virtues of good humour and avoid those bad manners which are its antithesis. "To command is nothing," said Marshal Foch, "to understand one another is the secret of life." Given full knowledge of the facts and the aid of a friendly atmosphere, industrial disputes should be soluble without conflict and its attendant hardship. There must, however, be a clear realisation of the fact that any machine or procedure which does not function usefully is just junk and should be scrapped. Great is the overall need for individual effort, which cannot be promoted by Acts of Parliament. It grows only by widespread realisation that everything depends, in the long run, upon our individual exertions. Conscientious effort—and this applies alike to workmen, managements and governments—is an obligation resting on everybody. If this truth were sufficiently apprehended, industrial affairs in Great Britain would be influenced in the right direction as surely as the flight of the arrow is controlled by the action of the archer. What we have to do at this milestone in our history is to infuse new vigour into our individual tasks and, with an honest concern for each other's problems, go forward in undivided strength. Reason is a far better guide than rhetoric, but if we cannot avoid polemics let us keep clear of that offensiveness in controversy which is the bane of all concord. Not for the first time do we face a situation fraught with peril and we can be encouraged by the oft-quoted words of Virgil to believe that the time may come when this present plight shall be sweet to remember (*Forsan et haec olim meminisse juvabit*). It depends upon what we learn—engineers, industrialists, trade unionists and politicians alike—from the difficulties which have overtaken us and upon our recognising the thinness of the ice over which we have long been skating. In examining all proposals for the strengthening of our national and industrial foundations, let us not forget the words of Lord Melbourne who, on a perilous occasion over a century ago is said to have remarked that "What all the wise men promised has not happened and what all the damned fools said would happen has come to pass."

Salvaging of the "Empress of Canada"

By CAPTAIN W. R. COLBECK, R.N.R.*

No. I

Here reprinted are abstracts from the twenty-ninth Thomas Lowe Gray Lecture presented before the Institution of Mechanical Engineers last Friday, January 18. In January, 1953, the "Empress of Canada," a passenger liner of 20,021 gross tons, sank on her side in Gladstone Dock, Liverpool, as a result of a fire. The events leading to the loss and the operations of uprighting and refloating are described with details of methods and materials used and the difficulties encountered.

ON the afternoon of Sunday, January 25, 1953, the S.S. "Empress of Canada" was lying in No. 1 Branch Gladstone Dock, when an outbreak of fire was discovered in the passenger accommodation, "B" deck. She had moved from graving dock two days previously, but her repairs were still in progress and about 290 workmen were on board, work including riveting of shell plating on the starboard side and various engine repairs. The ship was in charge of an officer with three engineers and a number of deck, engine-room and catering ratings and fire patrolmen.

The fire was discovered on board at 4.10 p.m., the alarm being telephoned to the fire brigade at 4.17 p.m., but at the official inquiry it transpired that smoke had been seen coming from portholes in "B" deck at between 3.25 p.m. and 3.30 p.m., that is forty to forty-five minutes before any alarm was given. The fire brigade arrived two minutes after the alarm at 4.19 p.m. and by that time the fire had obtained a firm hold and was spreading aft and upward with such rapidity that all that could be done was to attempt to "box" it. The number of fire pumps was eventually increased to thirty, supplemented by hoses from the Board's vessel "Salvor."

The Board's officials arrived shortly after 5 p.m. and we immediately investigated the stability of the ship. The officer of the day managed with some risk to recover the tank statement from the ship's office which gave amounts of fuel, water and stores on board, the ship having bunkered the previous day, and the estimated metacentric height (GM). There was no cargo. Although access to the ship's data and plans was not possible, fortunately a sister ship—the "Empress of France"—was lying in the next berth. Using the plans and data of the "Empress of France," the GM obtained with the stated amounts of fuel, &c., for the "Empress of Canada" agreed with the GM of 3·5ft calculated the previous day by the chief officer of the latter vessel, and with that check it was reasonable to use the "Empress of France's" data for further calculations.

Estimates were made of the amount of water entering the vessel through the fire hoses and the areas where it was being applied, together with estimates of the quantity of water that would drain to a lower level by way of staircases, &c., and the loss of weight due to combustion of wood panelling and fittings. On this basis it was calculated that when the vessel reached a list of 17 deg.–18 deg. the GM would be less than 6in, as the bulk of the water would be in the upper decks, and that there would be no righting moment left at a list of 22½ deg. An examination of the plans showed that with a list of 17 deg., the portholes on "D" deck would be below water level but, as all these were fixed ports of 1¼in glass and no repairs were in progress below "C" deck, no leakage was anticipated. Consideration was given to moving the vessel, but there were not sufficient tugs available to tow her with safety, and the possibility of blocking the only entrance to the North system of docks had to be weighed.

At the commencement of the fire the draught of the vessel was 18ft 2in forward and 25ft 2in aft (21ft 8in mean). The depth of water in the berth was 48ft–49ft and this level could not be lowered to any extent as the tide was rising. This precluded any hope of successfully grounding the ship by flooding. It was therefore decided to continue to fight the fire until the list reached 17 deg., and then to suspend fire fighting until the list reduced by the burning out of top weight and the reduction in weight of water by drainage and evaporation. As the bridge was in the fire area, a pendulum was rigged and a scale marked on the after end of the deckhouse on "A" deck aft, to enable the list to be measured. A number of holes were cut with oxy-acetylene torches in the shell plating at the level of "B" deck to drain that deck. The list steadily increased, and at 2035 hours it reached 17½ deg. The firemen inside the ship were withdrawn and fire fighting was confined to cooling the upper deck where surplus water would run overboard, and to protecting the shed alongside which the vessel was lying.

Meanwhile, detailed plans of the vessel had been obtained from the Canadian Pacific Company's head office and these were examined in conjunction with their naval architect to see if it was possible to improve the list by counterflooding. A pipe tunnel ran on the centre-line from the boiler-room forward through Nos. 2 and 3 holds to a height of 6ft above the hold ceiling and,

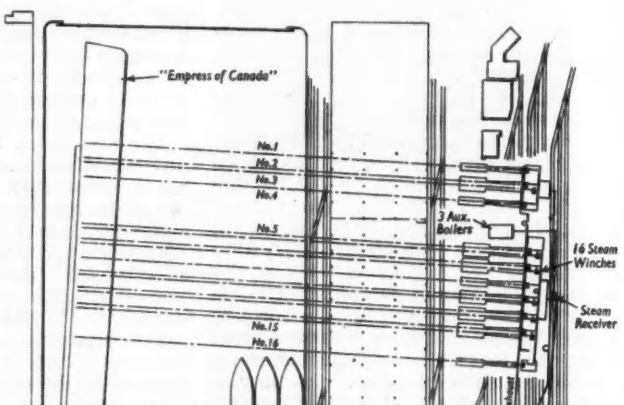


Fig. 2—General arrangement of winches and wires

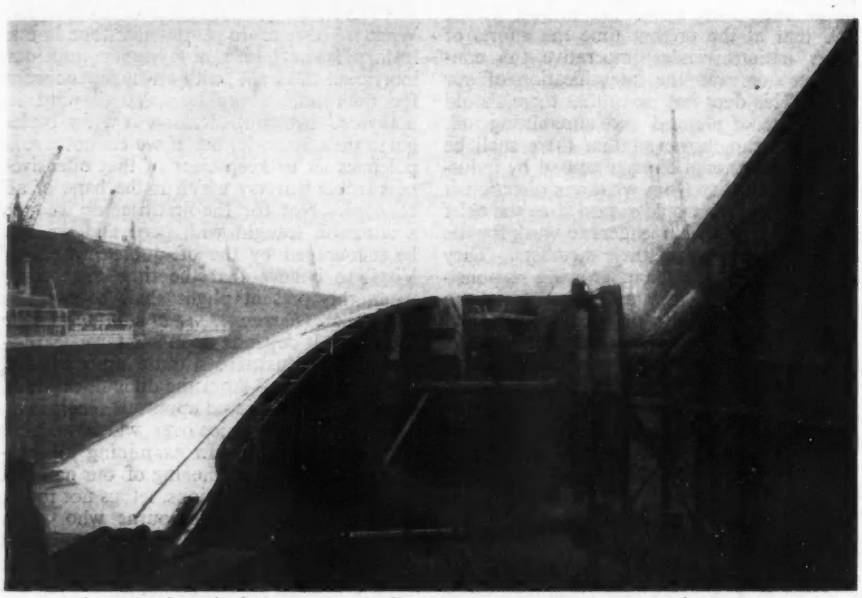


Fig. 1—S.S. "Empress of Canada," Gladstone Dock, January 26, 1953

* Marine Surveyor and Water Bailiff, Mersey Docks and Harbour Board.

from the plans, it appeared practicable to flood the starboard side of No. 3, hold but, after a short time, it was found that most of this water was draining to the port side through a cross-over pipe under the tunnel which was not shown on any of the plans, and the pumping was stopped.

The ship continued to increase her list and also her draught aft, at 2345 hours the list being 21 deg. and the draught 18ft 10in forward and 25ft 10in aft. About 0100 hours the masts and funnels came into contact with the dock shed and she finally sank on her side at 0138 hours on January 26 (Fig. 1).

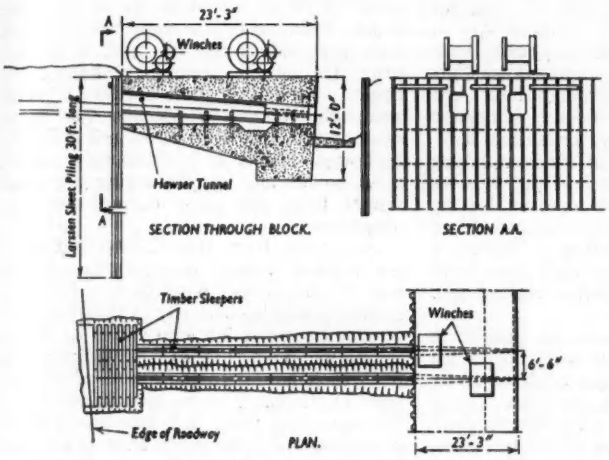


Fig. 3—Winch anchorage block

At the official inquiry, which was held before the vessel was salved, the probable cause of the steady increase of list was considered to be due to ingress of water through ports in "D" and "C" decks broken by the heat and through the galley refuse chutes in "C" deck. When, however, the vessel was uprighted it was found that the port oil fuel filling door on "D" deck level was open, providing an aperture 3ft by 2ft 3in which would be submerged at a list of 15 deg., and this was undoubtedly the major factor in the loss of the vessel. There was no reason for the door to be open and the fact that it was open was unknown to anyone in authority and, as it was below the level of the quay, it could not be seen when operations were in progress. It is not normal practice for such doors to be opened except when bunkering is in progress, and the starboard door through which the vessel had bunkered the previous day was properly closed and watertight.

The vessel sank on her port side, her masts and funnel resting on the quay and shed, lying at an angle of 89 deg. to the vertical. The bed of the dock consisted of sandstone overlaid with from 2ft to 4ft of soft mud, the original excavation of the rock being to a level of 22ft below low water of equinoctial spring tides. She was lying at an angle of 2·3 deg. to the face of the quay, the bow being about 35ft farther from the quay than the stern.

The dimensions of the ship were 581·9ft long, 75·25ft broad, and 24ft deep, with a gross tonnage of 20,021 tons. From the floating draughts her displacement immediately prior to the fire was 18,680 tons and, after subtracting the amounts of water, fuel, &c., this figure substantially agreed with the stated light ship displacement of 15,562 tons.

The "Empress of Canada" was launched in 1928 and, in view of her age and the damage she had sustained, it was probable that she would be a constructive total loss when salved. She was blocking a valuable berth but it was also important in planning her removal to cause as little interference as possible with the remainder of berths in the dock. The two alternatives were to cut her up where she lay or to upright and refloat.

Since the level of the dock water could only be lowered on rare occasions if the remaining deep-water berths, eleven in number, were to continue in use, the greater part of the cutting would have had to be done by divers and, even if the restrictions on the use of the dock were accepted, a third of the hull would always be submerged Previous experience in the removal of the remains of a small war casualty in the docks suggested that a period of three to four years would be occupied in this method, mainly owing to the difficulties caused by lack of visibility under water. The cost of the building of a dam round the vessel, to enable her to be cut up dry, and the subsequent removal of the dam was prohibitive. It was therefore decided to upright the vessel and then refloat. Preliminary calculations allowing for the removal of a large part of the superstructure showed that a total uprighting moment of about 350,000ft-tons would be required initially, decreasing as she turned and becoming zero at about 45 deg., and detailed planning to provide this force proceeded.

Meanwhile work proceeded on the removal of the masts, funnels, bridge, deckhouses, lifeboats, davits and cargo winches, each item being listed and weighed after removal. Owing to losses caused by locking operations, the level of the dock water fluctuated over a range of up to 10ft, occasionally being as low as 40ft, but over 50 per cent of this material had to be cut away under water by divers working under conditions of very low visibility.

The straight side of the vessel extended for a length of 230ft amidships and, allowing for a certain amount of cushioning by the mud overlaying the rock, a pressure of about 65 tons per square foot would develop as the vessel rolled on her bilge. A detailed examination of the scantlings showed that the strength of the structure in this area would serve to prevent collapse of the bilge.

A detailed examination was made of the interior of the vessel and the dock was run down at low water to enable as much as possible of this survey to be done dry, although over one-third still had to be done by divers. To assist the divers, a sectional model to a scale of ½in to 1ft was made, so constructed that each deck could be lifted off. All steel bulkheads, doors, &c., were built up in plywood, but wood bulkheads, fittings and machinery were shown in plan only on each deck, and the plan was marked up as the survey proceeded. The model proved of great value in the survey and in the work of isolating various compartments.

The uprighting moment was obtained from the combination of four forces, one mechanical and three static, as follows :—

(1) Sixteen shore purchases each nominally 100 tons, pulling on wires led over tripods erected on the starboard side.

(2) Eleven salvage pontoons submerged along the port deck edge.

(3) Six salvage pontoons partly filled with water as counterweights along the starboard bilge.

(4) Internal buoyancy in eight compartments in the hull.

The south quay of No. 1 branch dock has a three-storey concrete shed, the upper floors being carried on concrete pillars, the sides consisting mainly of large sliding doors. On the quayside of the shed is a 40ft wide apron with rail and crane tracks, and behind the shed is a service road 77ft in width. South of the road is a large railway siding.

To enable this berth to remain in use as long as possible, the anchorage for the purchases and seating for the winches was sited in the rail sidings about 150ft south of the shed, the positions of the tripods on the wreck and the anchorage of the purchases being arranged so that the lead of the hauling wires was at right angles to the wreck and clear of the shed pillars. With the large door area, only one reinforced concrete panel had to be removed from the roadside wall of the shed. The arrangement of the winches, wires, &c., is shown in Fig. 2.

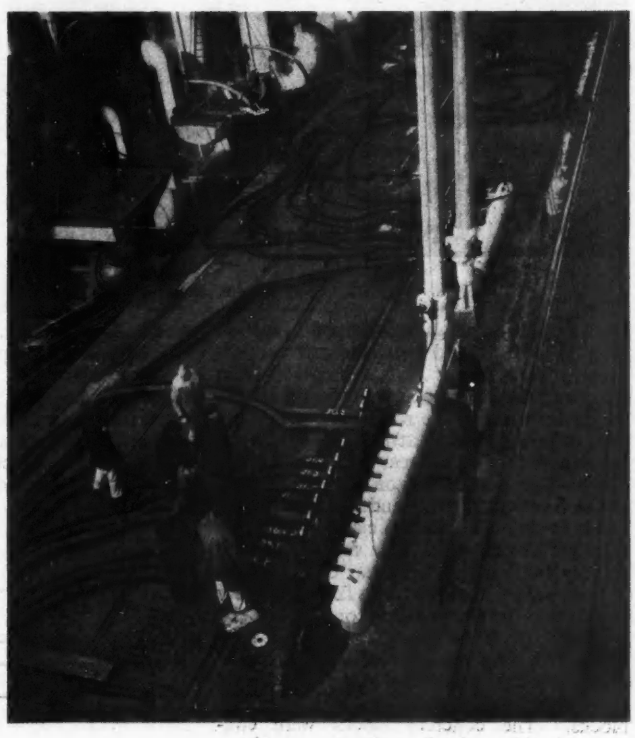


Fig. 4—Steam supply headers

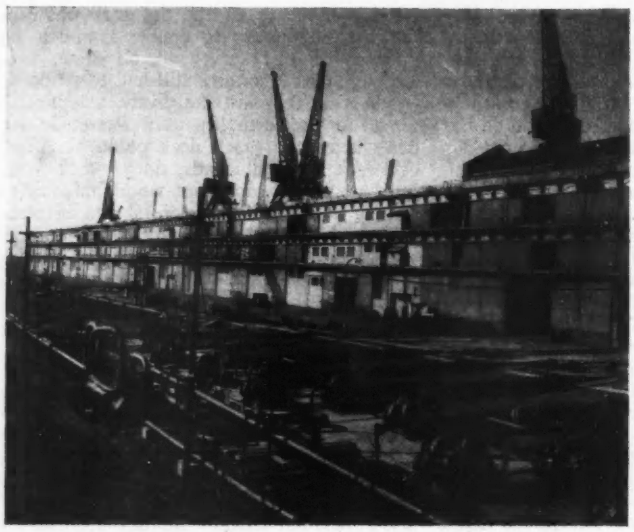


Fig. 5—Winches, steam receiver and pipe bridge

Anchorage Blocks.—Three reinforced concrete blocks were constructed to anchor the purchases and provide seating for the sixteen steam winches, carrying four, eleven and one winch respectively. The first block in plan measured 23ft 3in by 68ft, weighing 936 tons ; the second, 23ft 3in by 176ft, weighing 2420 tons, and the third, 23ft 3in by 16ft, weighing 220 tons.

In the design, a pull of 1920 tons, or 120 tons on each purchase, was allowed. The blocks were roughly wedge-shaped in section (Fig. 3), being 12ft deep at the rear end, 6ft deep in front, with a 2ft base step 16ft from the front, the centre of gravity being 1ft 6in off centre towards the rear. The maximum ground pressure when at rest was 0·869 ton per square foot at the rear edge, and, under full load, it was 0·941 ton per square foot at the front edge. The tendency was for the block to slide about a slip circle of approximately 54ft radius, giving a factor of safety of only 1·17, taking the shear of the soil at 0·1 ton per square foot. This factor of safety could not be increased economically by deepening the blocks, and Larssen sheet steel piling 30ft long was driven in front of the blocks throughout, the top of the piling being secured by heavy bolts at the top of the blocks. The concrete blocks were constructed of 8 to 1 mix and laid in sections, the joints having shear locks throughout, each joint being suitably reinforced with old steel rails. The first lifts were laid 6ft 6in deep forming the sloping bases.

To position the winches, openings 9ft by 6ft 6in by 2ft 3in deep were left on the top of the blocks. Two old steel rails were then temporarily fixed over each opening and levelled and the winches were lowered on to these supports with the holding-down bolts suspended into the openings. Concrete was then laid and levelled off 2in from the top face and the winches were removed, leaving the bolts concreted into position. Hardwood pads were then fitted and levelled and the winches bedded into position.

Trenches were excavated to provide a passage for the anchorage pendants to the tunnels in the block sloping from the roadway level to a depth of 5ft at the block. Each purchase was anchored by a 9in wire pendant, shackled to the rear block of the purchase, led through a tunnel cast in the block and secured by a 6in diameter carbon-steel toggle pin bearing against two steel girders cast in the rear face. An inspection passage for the rear toggle pins was provided at the rear face, the earth being retained by light sheet piling. Over 1000 yards of railway track had to be lifted to clear the site before excavation commenced. The surface level of the concrete blocks was arranged so that the railway tracks could be relaid across the top of them when the site was reinstated.

Winches and Steam Supply.—The heaving power was provided by sixteen steam winches of nominal 12-ton pull, loaned by the Admiralty, having cylinders 10½in diameter by 12in stroke. Although the size of the main drums was not ideal, the delivery period of specially built winches, either steam or electric driven, was so long that the restriction on the amount of purchase wire that the main barrels would accommodate had to be accepted.

The main steam supply was from six of the Board's dredging craft moored on the south quay, capable of supplying 120,000 lb of steam per hour at 180 lb per square inch. It was desirable to use these vessels for as short a period as possible, and, to provide steam for all the preliminary testing and rigging of the gear, three portable oil-fired, water-tube boilers, supplying 5000 lb of steam per hour, were positioned near the anchorage blocks in a temporary shelter, these boilers also supplementing the steam supply from the ships during the main operation.

The steam from the oil-fired boilers of the moored vessels was led through 3in bore flexible copper pipes to two 12in bore headers placed horizontally on the quay, each fitted with twelve 3in stop valves to receive the flexible pipes (Fig. 4). An 8in pipe rose from each header to the apron of the first floor of the shed, where they joined into a 10in bore main pipe. The 10in pipe was laid across the first floor of the shed and carried over the roadway on the south side on a temporary steel bridge, to leave the road clear for traffic. It then dropped to about 6ft above ground level and was laid with a slight gradient to the rear of the blocks, where it was connected to a steam receiver of 380 cubic feet capacity, the supply from the portable boilers being connected to the same receiver (Fig. 5). At the mid-length of the receiver the steam passed through a 10in control valve to the sixteen winches.

When heaving, the stop valves at the

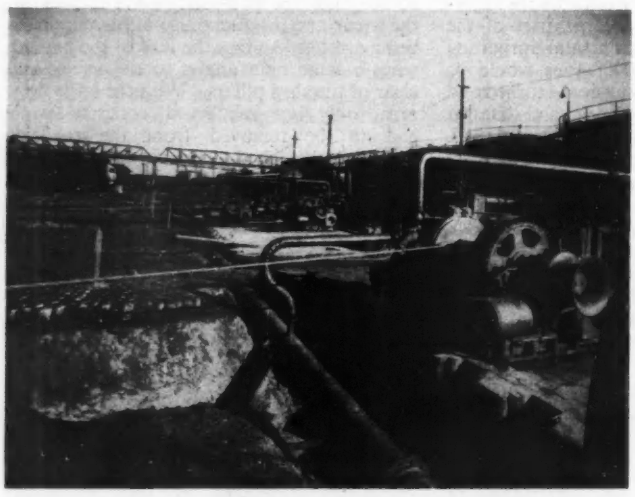


Fig. 6—Winches showing exhaust steam line

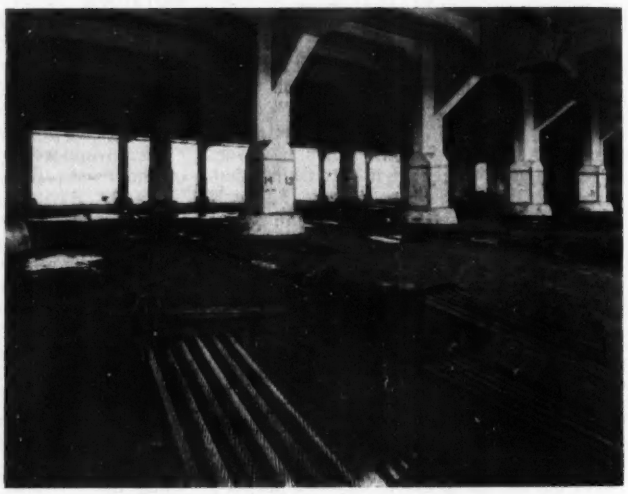


Fig. 7—Purchases, moving blocks and pendants

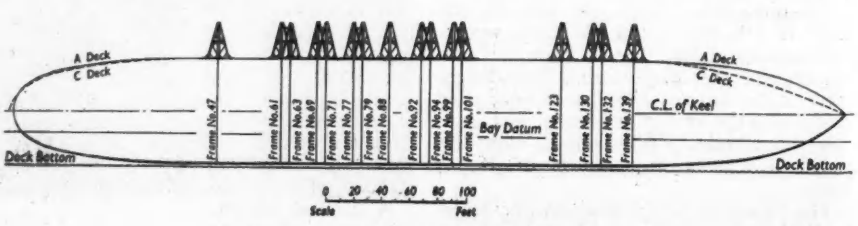


Fig. 8—Positions of tripods

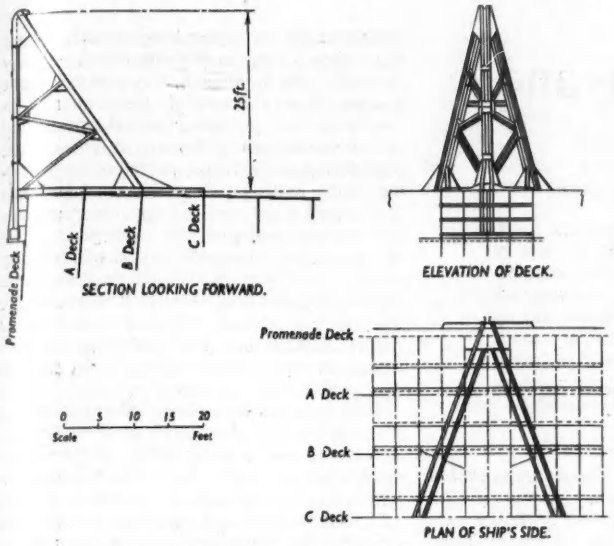


Fig. 9—Arrangement of single tripods on ship's side

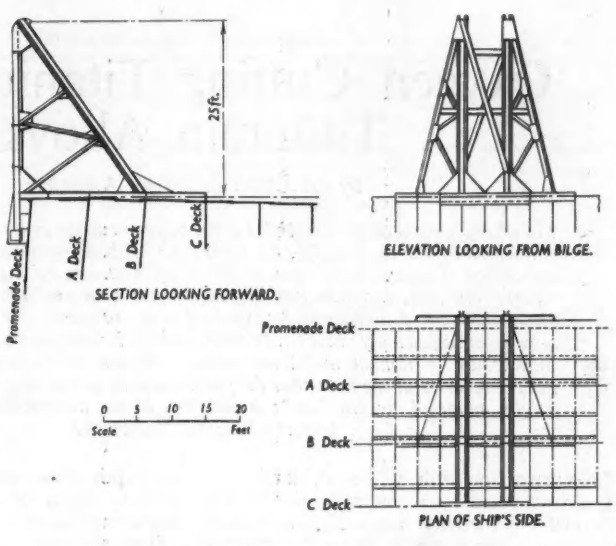


Fig. 10—Arrangement of double tripods on ship's side

winches were fully opened, and the steam supply was controlled from the main valve at the receiver to ensure that the pull of all the winches was as far as possible balanced. The headers, steam pipes, and receivers were lagged with 2in magnesia sections, canvas covered, and finally covered with $\frac{3}{8}$in "Bitulac" composition. Bradford type steam traps and hand drains were fitted at various points in the system. The 3in exhaust pipes from each winch were led into a common exhaust line laid along the north face of the blocks (Fig. 6), and exhausting to air at a distance of 250ft from the most westerly winch to keep the steam clear of the operating area. This pipe was of 8in bore at the eastern end and, at the fifth winch, increased to 10in bore, finally increasing to 12in bore to the outlet.

Purchases and Hauling Wire.—Each purchase comprised a pair of six sheave blocks rove with 3½in circumference steel wire rope. The rear block was shackled to a 9in steel wire pendant 100ft in length, passing through the tunnel in the concrete anchorage and secured with a 6in diameter toggle pin at the rear face. The outer or moving block was shackled to a 9in wire pendant, 60ft long, which, in turn, was shackled to the main wire (Fig. 7). The travel of the moving block was limited to about 75ft, this being governed by the maximum amount of 3½in wire which the barrels of the winches could accommodate. A travel of 75ft would produce an alteration in the angle of heel of the wreck of about 45 deg., and since at this list the wreck would still require power to move her towards the upright position, the 60ft pendants enabled the purchases to be fleeted out and reshackled to the main wire, as necessary, during the operations. The hauling part of the purchase wire ran from the outer block to the winch barrel, the other end being shackled to the same block using a "Talurit" alloy clamp to secure the wire round the thimble. The use of this type of clamp instead of a conventional splice permitted the blocks to be brought much closer together at the end of their travel.

The main 9in wires were led across the dock over the heads of the tripods and secured at the base of the vertical leg of the tripods. The 9in wires were of 6×61 construction with a breaking strain of 267·3 tons, similar to the wire used for lifting operations with camels. The 3½in wires were of 6×37 construction with a breaking strain of 43·5 tons. The ground over which the purchase blocks travelled was carefully swept and, where necessary, steel plates were laid to obviate the risk of grit and stones being picked up by the moving wires. Short lengths of old rail were secured at right angles to the moving blocks to prevent any tendency to twist under load. The distance from the heads of the tripods to the rear face of the concrete anchorage varied from 708ft to 735ft. The total length of 9in wire was about 11,000ft, and 24,000ft of 3½in wire was required for the purchases.

Tripods.—Sixteen tripods were constructed on the starboard shell plating, four single and six double, their positions being governed by the positions of the pillars in the south shed and by the condition of the ship's structure (Fig. 8).

Fig. 11—Completed tripods, looking forward

The vertical leg of No. 1 tripod was at "A" deck, the remainder being at the promenade deck, The tripods were fabricated from 28–32-tons-per-square-inch weldable mild steel plates and sections.

The vertical leg consisted of two 8in by 3½in by $\frac{5}{8}$in angles welded to the back of a 12in by 4in by 4in by 0·40/0·60in channel forming an 8in deep trough for the wire. Each back leg was made from two similar channels, back to back, with a 12in separation connected at intervals by 12in by 12in by $\frac{5}{8}$in plates. The curved bearing plate at the head was rolled from 1in plate and the legs were braced with 6in by 4in by $\frac{5}{8}$in angles.

The lower ends of the vertical legs extended 6ft 6in below the shell over the face of the deck, and were welded to three vertical plates 1in thick, welded to the deck extending fore-and-aft over five deck beams (Fig. 9). The base of the single tripods consisted of two fabricated girders in the form of a "V" extending over four decks and seven frames, the rear legs being connected to the base at the third deck. Each base girder consisted of two 15in deep plates, $\frac{3}{4}$in thick, 12in apart, continuously welded to the shell plating with a 4in by $\frac{3}{4}$in strip welded to the upper edge to form a flange, heavy tripping brackets being fitted at each deck. To ensure that the lower edge was in continuous contact with the shell plating, a pattern had to be made for each plate, and the plate cut to allow for landings, and the distortion caused by the fire (Fig. 10). The double tripods had two similar base members fitted parallel to the frames extending over four decks with similar girders at right-angles, extending fore-and-aft over nine frames at the line of the third deck.

The 9in wires were led over the curved bearing plate at the apices of the tripods down between the girders of the vertical legs and the ends were secured by 6in diameter toggle pins fitted in the side plates at the bases of the legs, and through the thimbles spliced in the ends of the wires, the pins being held in place by keep plates. The main parts of the tripods were fabricated ashore, placed in position by floating crane and welded up.

After completion each structure was tested by reeving a temporary 9in wire from the anchorage over the bearing plate and down over the bilge, where it was made fast to a camel. The camel was then partly flooded to produce a load on the wire equivalent to a horizontal pull of 150 tons at the head of the structure and deflections were checked. The maximum depression at the heel of the rear legs was $\frac{1}{2}$in (Fig. 11).

(*To be continued*)

Oxygen Cutting Titanium and Titanium Alloys

By G. COATES, M.A., A.Inst.P.*

Knowledge gained on the principles of the oxygen cutting process in iron and steel, stimulated by the work of Dr. A. A. Wells,[1] enabled predictions to be made of the ability of various substances to be cut by a stream of highly-purity oxygen. Apart from iron, titanium was the only metal then available on a commercial scale which could confidently be expected to be cut easily. A few simple cutting tests gave surprisingly successful results and work was put in hand to cut various thicknesses of titanium metal and alloy. Results are reported here. It was not appreciated at the time that the process was known in the U.S.A. and had been briefly reported by Everhart[2]; it was looked for independently by the British Welding Research Association.

IN comparison with mild steel, titanium is characterised by a lower density, lower thermal conductivity but a higher melting point and a much greater affinity for oxygen. In flame cutting, the heat formed by combustion with oxygen is greatly in excess of the losses by conduction through the sides of the cut, and consequently titanium cuts with great rapidity. The ignition temperature is fairly high (about 1100 deg. Cent.), but once having started the cut it can be made to progress at least five times faster than for steel of equivalent thickness. In general, the limiting speed has not yet been determined since the carriages of existing flame-cutting heads do not move fast enough. Satisfactory cuts can be made in titanium with equipment designed for work in mild steel, but almost certainly greater economy could be achieved by producing new designs or modifications.

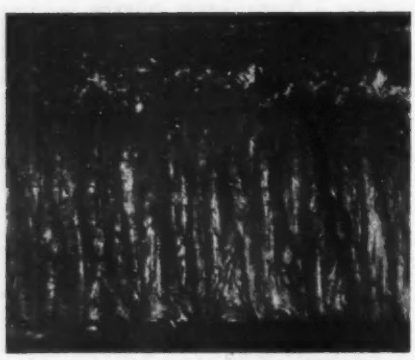


Fig. 1—Cut in stack of four 0·065in thick pieces of titanium alloy (5% Al, 2½% Sn). Oxygen gauge pressure 25 p.s.i. Cutting orifice diameter, 0·031in, speed 24in per min.

Examples of Actual Cuts

Successful cuts have been made in titanium sheet or plate from thicknesses of $\frac{1}{16}$in to 3in and in a 9in diameter Ti 150 cylindrical billet. The first successful cut (see Fig. 1) was in a stack of four 0·065in thick sheets lightly clamped together. The stacking was fortuitous, but subsequent experience has suggested that stack cutting of titanium should be possible even if slight gaps between the sheets remain, so that tight clamping would be unnecessary. As the mass of kerf metal removed will, however, increase with the depth of the stack, the economy of such a process might be limited. A cut in $\frac{1}{4}$in thick single sheet is shown in Fig. 2.

The severance of a 9in diameter billet presented a more difficult problem, but a typical result is shown in Fig. 3. The metal

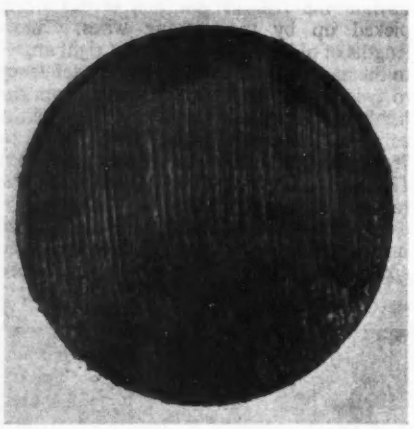


Fig. 3—Cut in 9in diameter Ti 150 alloy billet. Oxygen gauge pressure 200 p.s.i. Cutting orifice diameter 0·150in, speed 20in per min.

cuts readily even though the tip of the nozzle is several inches above it, so that rather than follow the upper profile of the billet, it is simpler to fix the nozzle to clear the highest point by about $\frac{1}{4}$in and make a horizontal traverse. Initiation is conveniently performed by melting the end of a steel welding rod and depositing a globule on the titanium surface; the globule is fired by the stream of cutting oxygen. This property of insensitivity to the gap between nozzle and surface means that pieces of irregular profile may be cut easily.

Metallurgical Problems Associated with Cutting

Titanium has two major forms, the α-type (hexagonal-close packed system) and the β-type (body-centred-cubic system). The latter prevails at higher temperatures (above 882·5 deg. Cent.) in pure titanium, but may be retained in the structure by heat treatment and by alloying elements. Consequently, in commercial alloys, there exists the possibility of transformation hardening at a flame cut edge owing to the rapid quench effect following flame cutting. An additional problem is the very high affinity which titanium has for oxygen, nitrogen and hydrogen. Since the principle of oxy-cutting depends upon the raising of the surface to the melting point in a highly oxidising stream, it is impossible to prevent surface oxidation and some micro-cracking so that additional surface treatment by mechanical methods may be required.

Fig. 4 shows a hardness plot taken in a plane at right angles to the combustion face of one of the 0·065in thick plates in the stack illustrated by Fig. 1. The depth of the hardened zone is seen to be about 0·05in, and micro-cracks are observed in this zone of about the same depth. Also illustrated is a hardness plot into the edge of a $\frac{1}{8}$in thick plate of commercially pure Ti and indicates that the hardened zone depth is also of the order of 0·05in. Fig. 5 shows similar hardness plots for materials of various thicknesses and indicates that the depth of hardening is virtually independent of thickness.

According to Meyer[3] hardness is a fair measure of oxygen contamination but not necessarily of brittleness, though it has been pointed out[4] that the material should be stabilised to minimise the transformation hardening effect before taking hardness plots. In general, the micro-cracks are at right angles to the drag lines and extend to a depth about equal to that which would require to be removed by subsequent machining to clear away the hardened zone. A detailed metallurgical examination is being made and various layers of surface contamination detected.[4]

The Influence of Alloying Elements

The affinity of titanium for oxygen is so great and its combustion so rapid that the possible retarding influence of the alloying elements yet encountered (including chromium) makes no noticeable difference. It is likely that alloy constituents up to a total of 10 per cent would not greatly affect rate of cutting.

With regard to the elements which follow the same theoretical rules as iron and titanium, another is vanadium, so that a number of binary or ternary alloys of the Fe-Ti-V system are probably "cuttable." One reservation is that, in the binary Fe-Ti system, an alloy of too low a melting point might not be amenable to treatment owing to the formation of an oxide slag of refractory nature.

Referring again to Meyer,[3] experiments with a trial melt of binary β-alloy of 25 per cent V-Ti composition, concluded that oxygen addition up to at least 0·4 per cent had no deleterious effects on weldability, so that the metallurgical problems associated with flame-cutting in such a case may not be so serious as with the more common α-type alloys, where much smaller amounts of oxygen contamination can be tolerated. Similar considerations might apply to other stable β-alloys, though they are not likely to be used widely owing to their unsatisfactory properties.

Comparison of Costs

Estimates have been drawn up of the minimum workable widths of cut, before and after cleaning up by machining, assuming

Fig. 2—Cut in $\frac{1}{4}$in thick commercially pure titanium. Oxygen gauge pressure 2 p.s.i. approx. Cutting orifice diameter 0·0225in, speed 48in per min.

* British Welding Research Association.

that two faces of each cut require post-burning treatment. Accurate comparative costing is not possible, but in the table an attempt has been made to compare sawing-plus-light machining with flame-cutting-plus-heavy machining as alternative methods of producing two flat uncontaminated surfaces. One surface is assumed to pertain to the workpiece and the other to reusable scrap. The data have been obtained as follows.

Sawing Times.—For rounds 1in and over data quoted by Doyle[5] are used, and relate to times for cutting pieces with a 26in diameter circular saw producing a cut equivalent to 0·25in loss of metal at a speed of 20 r.p.m. For thin sheets, note is taken of a reference by Ashburn[6] to hacksawing at a speed of sixty strokes per minute, with a feed of 0·012in per stroke, and a kerf graded with thickness. This gives a rate of 0·72in per minute or sixteen minutes per foot. This rate has been taken as accurate for ½in thickness and the rates for other thicknesses are assumed to be in proportion.

Machining Times.—Estimates for machining rates vary widely and to some extent depend on the type of alloy (especially on carbon content). A representative cost of machining (turning, planing, milling, grinding) is assumed to be equivalent to that of "shaping" the flame cut edge by taking a deep roughing cut with a tool averaging twenty useful strokes per minute with a cross feed of 0·015in per stroke,[6] making a rate for thickness or diameter of 0·3in per minute. This is followed up by a finishing cut (depth 0·002in to 0·010in) at the same speed.

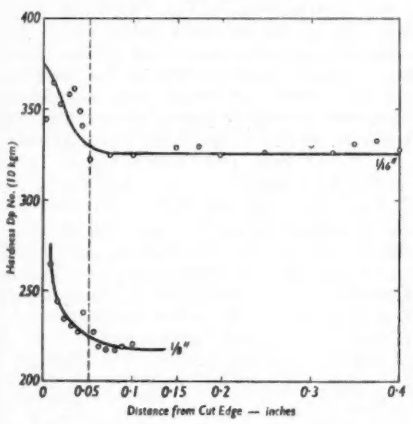


Fig. 4—Hardness survey of flame cut titanium alloy

Faster cuts might be made by grinding, with liquid or gaseous coolants, or by using a face milling cutter with replaceable blades of the type described by Fine and Meneleus,[7] but it is felt that time savings might be matched by additional costs in other directions (coolants, maintenance, &c.), so the general picture given would still apply.

Flame Cutting—Times.—Speeds up to 100in per minute could be used if desired (Everhart[2] quotes 140in per minute in one instance), but a modest value of 24in per minute has been taken, permitting a sufficient margin to account for preheat time.

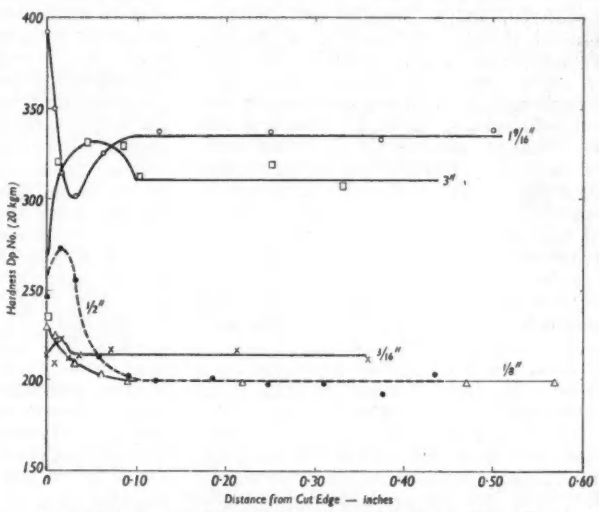
Labour (Time Costs).—A rate of 12s. per hour labour-plus-overheads has been adopted as a basis and has been used in the flame-cutting case. For sawing and machining an additional 3s. an hour is added to account for interest (5 per cent) and depreciation (10 per cent) rates on machinery valued at £1100 used 50 per cent of the time in a fifty-week year of forty-four-hour weeks.

Cost Comparisons for Titanium Cutting

Material form	Thickness or diameter	Saw or flame time	(I) Cost (saw or flame)	Machine time per surface	(II) Cost (m/c.)	Estimated Ti losses			(III) Cost Ti	Total cost (I+II+III)	Total time
						Width	Volume	Weight			
	Inch	Minutes	Shillings	Minutes	Shillings	Inch	Cubic inches	Pounds	Shillings	Shillings	Minutes
Sawing and Clean-up Machining:											
Flat bar (per 12in)	¼	4	1·0	0·4	0·2	0·07	0·1	0·02	1·6	2·8	4·8
	½	16	4·0	1·7	0·8	0·14	0·8	0·13	10·4	15·2	19·4
	1	32	8·0	3·3	1·7	0·25	3·0	0·49	39·2	48·9	38·6
	2	64	16·0	6·7	3·3	0·25	6·0	0·98	78·4	97·7	77·4
	3	96	24·0	10·0	5·0	0·25	9·0	1·47	117·6	146·6	116·0
Round bar or billet (X.Sn)	1	8	2·0	3·3	1·8	0·25	0·20	0·032	2·6	6·4	14·6
	1½	10	2·5	4·2	2·2	0·25	0·3	0·05	4·0	8·7	18·4
	2	15	3·8	6·7	3·3	0·25	0·8	0·13	10·4	17·5	28·4
	4	75	18·8	13·3	6·7	0·25	3·0	0·49	39·2	64·7	101·6
	9	240	60·0	30·0	15·0	0·25	16·0	2·6	208·0	283·0	300·0
Flame-cutting and Machining:											
Flat bar (per 12in)	¼	0·50	0·1	0·8	0·4	0·12	0·18	0·029	2·9	3·4	2·1
	½	0·50	0·1	3·3	1·7	0·12	0·7	0·12	12	13·8	7·1
	1	0·50	0·1	6·7	3·3	0·20	2·4	0·39	39	42·4	13·9
	2	0·50	0·1	13·3	6·7	0·26	6·3	1·02	102	108·8	27·1
	3	0·50	0·1	20·0	10·0	0·32	11·5	1·86	186	196·1	40·5
Round bar or billet (X.Sn)	1	0·04	0·0	6·7	3·3	0·20	0·16	0·026	2·6	5·9	13·4
	1½	0·05	0·0	8·4	4·2	0·21	0·3	0·04	4	8·2	16·9
	2	0·08	0·0	13·3	6·7	0·26	0·8	0·13	13	19·7	26·7
	4	0·17	0·0	26·7	13·4	0·40	5·1	0·82	82	95·4	53·6
	9	0·38	0·1	60·0	30·0	0·66	42·5	6·90	690	720·1	120·4

Titanium Metal Costs.—The metal lost, both by burning and rough machining, is valued at £5 per pound. Sawing swarf is regarded as capable of recycling (value £1 per pound) so its loss value is only £4 per pound. No allowance has been made for finish machining losses or recoveries.

Total Costs.—The total costs show slight differences between sawing and flame-cutting, with an advantage to the latter for sections of intermediate thickness, and in every case a considerable saving in time. Such a comparison is, naturally, only to be regarded as a pointer, and consumption items like electricity, cutting gases and machine tools, have not been allowed for. In general, it is concluded that in certain circumstances oxy-cutting might have an economic future. The situation depends to a large extent on the articles to be fabricated and is complicated by the absence of a genuine market for titanium scrap. The financial aspect of traditional costing depends mainly on the £5 per pound taken as the value of the titanium burnt. Admittedly, a recent article[7] quotes £7 6s. for semi-finished products (sheet, rod, &c.), but against this should be set the fact that the manufacture of parts which have to be cut out of bulk stock would involve the production of a fair amount of scrap, so that the kerf metal destroyed should be valued in such cases as only £1 per pound. This would make flame-cutting economic at present prices. The machining necessary to make the rejected pieces free from contamination has, of course, been allowed for.



Surface Hardness—¼" 225±9, ½" 205±2, ¾" 329+100—64, 1¼ 350±5, 3" 325
Maximum depth impression—0·003

Fig. 5—Hardness survey of flame cut titanium alloys

Possible Applications

The following applications of flame cutting could be considered:

(*a*) Cropping of billets and trimming of thick sections in the early stage of production.

(*b*) Preparation of sections for welding.

(*c*) Scrap cutting.

A 9in section which would take hours to saw may be flame-cut in a few minutes. Although, for very thick sections, flame-cutting is not favoured by comparison with sawing on the basis described so far, it should be remembered that the most important feature is that of the cost of the metal, which is generally thought to be likely to fall as production rates rise in future. Furthermore, the width of cut is approximately proportional to the depth of the maximum section, which is the diameter in the case of a cylinder. Accordingly, a rectangular billet would be more economical than a cylindrical one if flame-cutting had to be performed. One aid to faster cutting could be the arranging of a number of sections in a line, and making a simple cut across. A strip of scrap material across the surfaces of the adjacent sections might be sufficient to enable a cut to progress across the gaps.

Another possible technique might be to revolve a cylindrical billet whilst cutting so that the maximum depth of cut at any time were less than the diameter. Calculations show a reduction to $1/\sqrt{2}$ of the diameter with proportionate saving in loss of metal.

In the preparation of sections for welding, the major problem is the contamination of the surface layer by gaseous constituents which could cause the weld metal to be similarly contaminated although welding is conducted in an inert atmosphere. No doubt the most serious contamination is in the surface slag and this could be removed easily by a few passages of an ordinary grinding wheel. The determination of the amount of flame-cut edge to be removed in order to prepare a sufficiently clean surface for welding would be an important item for research.

The use of an oxy-acetylene flame for cutting titanium scrap is probably of little interest at the present time. As the industrial use of titanium alloys develops, a time will eventually be reached when components and constructions become redundant. A material which may be so rapidly cut out and subdivided can be attractive in such a context. In the field of corrosion resistance, titanium alloys are reputed to have properties equal, or in some cases superior, to those of stainless steel. Many alloy steels present considerable gas-cutting problems which tend to limit their field of application and such restrictions would not apply to titanium.

ACKNOWLEDGMENTS

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A Victorian Apprenticeship

By H. E. WIMPERIS

WITHIN living memory it was the custom for almost all those who wished to become mechanical or electrical engineers to pursue an apprenticeship course of some form or kind. Sixteen was a not uncommon age for being indentured, and a five-year term was not unusual, though some did not stay so long. Such apprentices paid a premium on entry, or were admitted without any such formality if they happened to be the sons of workmen linked in some way with the factory concerned. But whichever the mode of entry the conditions of employment were much the same, and certainly the hours were long and the pay very small. At the works in which, as it happened, the writer was apprenticed, the usual fifty-four-hour week began each day at 6 a.m. and the pay rose slowly from the weekly five shillings at which it began but made, of course, a sudden jump when the journeyman stage was reached. Such conditions would no doubt be very far from being acceptable in the conditions prevailing to-day.

As it happens there is at the present time a widespread feeling that the number of trained mechanicians in Britain is now a great deal lower than it should be, whilst the higher grade of technologist is in worse condition still : our figures compare very unfavourably, indeed, with those of U.S.A. or U.S.S.R., even when allowance is made for our far smaller population. No doubt it was this factor which caused our learned contemporary *The Economist* to devote recently some pages to a discussion on "Apprenticeship for Skill." It was there estimated that the remarkable post-war bulge in British birth-rate figures must lead to there being this year some 679,000 boys and girls of fifteen years of age, rising five years later to the very considerable figure of no less than 930,000. After reaching that height it is expected to fall ; but in the meanwhile, Britain will have a fine opportunity to make good the present shortage of skilled workers and be the better equipped to meet the era of automation, with its call for large numbers of skilled supervisors of electronic and other novel devices. These, though they will naturally decrease the demand for unskilled labour, will call for a far larger number of those equipped for the vital task of skilled supervision and, whenever necessary, the adjustment and repair of the apparatus in use.

It is fortunately common nowadays for industrial firms, especially the larger ones, to allow their indentured apprentices to have the advantage —without loss of pay—of part-time study during the working day, and encouragement is often given for evening study on one or two nights a week as well. There are also, in some cases, "sandwich courses" of various sorts which allow certain student-apprentices to take advantage of regular college tuition. According to official figures (for 1954) the proportion of boys aged between fifteen and seventeen who were apprenticed was as high as 35 per cent and even more in some industries. This represents a welcome change, since there had been observed in past years a most regrettable tendency for boys on leaving school to seek work which, even though it "led nowhere," had the attraction of being much better paid than was the immediate lot of the ordinary apprentice. It reflected also, of course, the natural effect of that "erosion of differentials," as between skilled and unskilled work, which caused lads to wonder whether the years of effort to become a skilled craftsman could really be worth while. In the long run it certainly is, of course ; but young people, whether in the exercise of the choice between the financial attraction of "jam to-day" rather than "jam tomorrow," or perhaps by some tendency towards indolence, cannot be expected always to reach wise decisions.

The writer's personal experience of an apprenticeship in Victorian days was of its being a happy one, but certainly strenuous. Work began at the Brighton Locomotive Works by six o'clock in the morning, often preceded by a hurried walk of half an hour or more to get to the works in good time. In those far-off days there was no release during working hours for technical school training of any sort ; such study had to be planned by the apprentice as best he could in the evenings, after the day's work. A very important officer, the then Locomotive Superintendent of the Brighton Railway, was the "instructor" to whom the apprentices were indentured ; but in the whole three years of the writer's period of training he never so much as exchanged a word with him—indeed, only saw him in the distance when he strolled—in a silk top hat—through the workshops ! But those below him were cordiality itself, from the chargeman of the "breakdown gang" who cautiously advised : "Now, my lad, when I send you off on a repairing job of any kind, don't try to mend it so that it can never break down again, or we shall be out of a job !" to the fitting shop foreman who, finding an apprentice, in between jobs, drawing with chalk on a face plate, tapped him on the back to say : "Now, my boy, remember that you are paid to work and not to think."

The course of workshop instruction which was followed was certainly comprehensive : first the machine shop for experience with shaping machines, planing machines and lathes ; then on bench work in the fitting shop, and later, if you were lucky, in the "tool gang," and perhaps even the "breakdown gang," with the most fascinatingly puzzling and instructive task of all. But release from work, even without pay, to attend classes of any sort was frowned upon : the writer once rashly asked "authority" for permission for such occasional release and received a blunt refusal—a most useful lesson, for it taught him never in future to "ask permission" for anything, but rely instead on one's own judgment of what was right and do that. The responsibility was then entirely your own, for you were not asking "authority" to share it, and almost certainly you would thereafter hear nothing more about it ! That bold procedure did not mean that one should never seek advice if it seemed necessary, and the writer can recollect writing to the then Astronomer Royal for advice on the best way in which one could learn to become an astronomer —with the pleasant result of Sir William Christie's cordial invitation to the writer to come and talk to him at Greenwich. This, of course, he did, and that wonderful day led to his receiving the advice, which he took, to make his way to Cambridge ; though subsequent years at Imperial College and at Cambridge did, as it happened, lead to other paths. For in the interval aviation had come to birth with its many fascinating scientific problems, and there was besides a real allure in invention.

Technical Reports

Sur La Stabilité Dynamique des Réseaux Interconnectes. By P. Willems. Ateliers de Constructions Electriques de Charleroi, Charleroi, Belgium. Free on application. Interconnection of electric networks is practised for economic reasons, as well as the technical one of maintaining the supply to the consumer in spite of various abnormal conditions causing partial breakdowns. When such changes occur they give rise to transients which must disappear if a new equilibrium is to be reached. The classical method of investigating network problems is by means of an a.c. network analyser, which is now considered as being an imperfect tool of research. Modern developments have been towards the wider use of modern digital and analogue computers. The author considers the application of such calculators to network problems with a view particularly to the following questions : dynamical behaviour of synchronous machines turning at variable speeds ; behaviour of network disturbed by abnormal functioning ; lastly, the question raised by the saturation of the machines is treated.

Transatlantic Telephone Cable

A symposium of papers on the first transatlantic telephone cable was presented yesterday at a joint meeting (using the cable link) of the Institution of Electrical Engineers, the American Institute of Electrical Engineers, and the Engineering Institute of Canada. The papers in the symposium described the design, manufacture and installation of the first transatlantic telephone cable system and its component parts, including the connecting microwave radio relay link in Nova Scotia. The symposium was introduced by a foreword given jointly by Dr. Mervyn J. Kelly, of the Bell Telephone Laboratories, and Sir Gordon Radley, of the General Post Office. This foreword, which is reproduced below, described the background of the transatlantic cable project and discussed its technical contribution to progress in world communications.

ELECTRICAL communication between the two sides of the North Atlantic started in 1866. In that year the laying of a telegraph cable between the British Isles and Newfoundland was successfully completed. Three previous attempts to establish transatlantic telegraph communication by submarine cable had failed. These failures are to-day seen to be the result of insufficient appreciation of the relation between the mechanical design of the cable and the stresses to which it is subjected as it is laid in the deep waters of the Atlantic. The making and laying of deep-sea cables was a new art, and designers had few experiments to guide them.

During the succeeding ninety years, submarine telegraph communication cables have been laid all over the world. Cable design has evolved from the simple structure of the first transatlantic telegraph cable—a stranded copper conductor, insulated with gutta-percha and finished off with servings of jute yarn and soft armouring wires—to the relatively complex structure of the modern coaxial cable, strengthened by high-tensile steel armouring for deep-sea operation. The coaxial structure of the conducting path is necessary for the transmission of the wide frequency bandwidth required for many telephone channels of communication. The optimum mechanical design of the structure for this first transoceanic telephone cable has been determined by many experiments in the laboratory and at sea. As a result, the cable engineer is confident that the risk of damage is exceedingly small, even when the cable has to be laid and recovered under conditions which impose tensile load approaching the breaking strength of the structure.

The great difference between the transatlantic telephone cable and all earlier transoceanic telegraph cables is, however, the inclusion of submerged repeaters as an integral part of the cable at equally spaced intervals, and the use of two separate cables in the long intercontinental section to provide a separate transmission path for each direction. The repeaters make possible a very large increase in the frequency bandwidth that can be transmitted. There are fifty-one of these submerged repeaters in each of the two cables connecting Clarenville in Newfoundland with Oban in Scotland. Each repeater provides 65 dB of amplication at 164 kc/s, the highest transmitted frequency. The working frequency range of 144 kc/s will provide thirty-five telephone channels in each cable and one channel to be used for telegraph traffic between the United Kingdom and Canada. Each cable is a one-way traffic lane, all the "go" channels being in one cable and all the "return" channels in the other.

The design of the repeaters used in the North Atlantic is based on the use of electronic valves and other components, initially constructed or selected for reliability in service, supported by many years of research at Bell Telephone Laboratories. Nevertheless, the use of so many repeaters in one cable at the bottom of the ocean has been a bold step forward, well beyond anything that has been attempted hitherto. There are some 300 valves and 6000 other components in the submerged repeaters of the system. Many of the repeaters are at depths exceeding 2000 fathoms (2¼ miles) and recovery of the cable and replacement of a faulty repeater might well be a protracted and expensive operation. This has provided the incentive for a design that provides a new order of reliability and long life.

On the North Atlantic section of the route, the repeater elements are housed in flexible containers that can pass around the normal cable-laying gear without requiring the ship to be stopped each time a repeater is laid. The advantages of this flexible housing have been apparent during the laying operations of 1955 and 1956. They have made it possible to continue laying cable and repeaters under weather conditions which would have made it extremely difficult to handle rigid repeater housings with the methods at present available.

A single connecting cable has been used across Cabot Strait between Newfoundland and Nova Scotia. The sixteen repeaters in this section have been arranged electronically to give both-way amplification, and the single cable provides "go" and "return" channels for sixty circuits. "Go" and "return" channels are disposed in separate frequency bands. The design is based closely on that used by the British Post Office in the North Sea. Use of a single cable for both-way transmission has many attractions, including that of flexibility in providing repeatered cable systems, but no means has yet been perfected of laying as part of a continuous operation the rigid repeater housings that are required because of the additional circuit elements. This is unimportant in relatively shallow water, but any operation that necessitates stopping a ship adds appreciably to the hazards of cable laying in very deep water.

The valves used in the repeaters between Newfoundland and Scotland are relatively inefficient judged by present-day standards. They have a mutual conductance of 1000 micromhos. Proven reliability, lower mechanical failure probability and long life were the criteria that determined their choice. Valves of much higher performance with a mutual conductance of 6000 micromhos are used in the Newfoundland–Nova Scotia cable, and it is to be expected that long repeatered cable systems of the future will use valves of similar performance. This will increase the amplification and enable a wider frequency band to be transmitted, thus assisting provision of a greater number of circuits. If every advantage is to be taken of the higher performance valves, it will be necessary to duplicate (or parallel) the amplifier elements of each repeater, in the manner described in a later paper, in order to assure adequately long trouble-free performance. This has the disadvantage of requiring the use of a larger repeater housing.

During the three years that have elapsed since the announcement in December, 1953, by the American Telephone and Telegraph Company, the British Post Office and the Canadian Overseas Telecommunication Corporation, of their intention to construct the first transatlantic telephone cable system, considerable progress has been made in the development and use of transistors. The low power drain and operating voltage required will make practicable a cable with many more submerged repeaters than at present. This will make possible a further widening of the transmission band, which could provide for more telephone circuits with accompanying decrease in cost per speech channel, or the widened band could be utilised for television transmission. Much work, however, is yet to be done to mature the transistor art to the level of that of the thermionic valve and thus ensure the constancy of characteristics and long trouble-free life that this transatlantic service demands.

The present transatlantic telephone cable whose technical properties are presented in the accompanying papers, however, gives promise of a large reduction in costs of transoceanic communications on routes where the traffic justifies the provision of large traffic capacity repeatered cables. The thirty-six 4 kc/s channels, which each cable of the two-way system provides, are the equivalent of at least 864 telegraph channels. A modern telegraph cable of the same length without repeaters would provide only one channel of the same speed. The first transatlantic telegraph cable operated at a much lower speed, and transmitted only three words per minute. The greater capacity of future cables will reduce still further the cost of each communication circuit provided in them. Such considerations point to the economic attractiveness, where traffic potentials justify it, of providing broad-band repeatered cables for all telephone, telegraph and teletype service across ocean barriers.

The new transatlantic telephone cable will supplement the service now provided by radio telephone between the European and North American continents. It will add greatly to the present traffic-handling capacity of this service. The first of these radio circuits was brought into operation between London and New York in 1927. As demands for service have grown, the number of circuits has been increased. We are, however, fast approaching a limit on further additions, as almost all possible frequency space has now been occupied. The submarine telephone cable has come, therefore, at an opportune time; further growth in traffic will not now be limited by traffic capacity.

Technical developments over the years by the British Post Office and Bell Telephone Laboratories have brought continuing improvement in the quality, continuity and reliability of the radio circuits. The use of high-frequency transmission on a single sideband with suppressed carrier and steerable receiving aerial are typical of these developments. Even so, the route, because of its location on the earth's surface, is particularly susceptible to ionospheric disturbances which produce quality deterioration and at times interrupt the service completely. The cable transmission will be free of all such quality and continuity limitations. In fact, service of the quality and reliability of the long-distance service in America and Western Europe will be possible. This quality and continuity improvement may well accelerate the growth in transatlantic traffic.

The British Post Office and Bell Telephone Laboratories are continuing vigorous programmes of research and development on submarine cable systems. Continuing technical advance can be anticipated. Broader transmission bands, lower cost systems and greater assurance of continuous, reliable and high-quality services will surely follow.

Slide Rule for Hydraulic Calculations

A SLIDE rule for hydraulic calculations has just been placed on the market, designed by Mr. J. Tarrant. One side of the rule is used for flow in pipes up to 100in in diameter running full. Scales are provided for flow, diameter of pipe, head lost and length of pipe, and when any three of these factors are known, the fourth can be found. There is also a scale for determining the velocity of flow. Scales on the lower edge of the rule enable the same information to be calculated for pipes and sewers running partly full, and a scale is also provided for ordinary multiplication and division. Calculations on this side of the slide rule are based on the Hazen-Williams formula for flow of water in pipes.

The other side of the rule is used for calculations of flow in open channels. The scales on this side are for velocity, hydraulic radius, slope of channel and Kutter's constant *n*. The hydraulic radius for channels bounded by straight lines can easily be determined, and for half-round channels having a depth of flow up to half the diameter, the hydraulic radius and area of flow can be calculated in conjunction with a set of additional scales provided on the lower right-hand part of the rule. The Manning formula is used for calculations on this side of the rule.

On both sides of the slide rule the scales are printed in black in English units with the equivalent metric units printed in red. Further information may be obtained from the Paterson Engineering Company, Ltd., Windsor House, Kingsway, London, W.C.2.

Metallurgical Topics

Nitrides in Aluminium Steels

ACCORDING to K. Born and W. Koch,[1] the decisive influence of a small addition of aluminium on the properties of a low-carbon steel is exercised by nitrogen in combination with the aluminium as aluminium nitride, AlN. This nitride produces fine grain size, makes the steel less subject to ageing and raises the yield point. Born and Koch devised an electrolytic method of

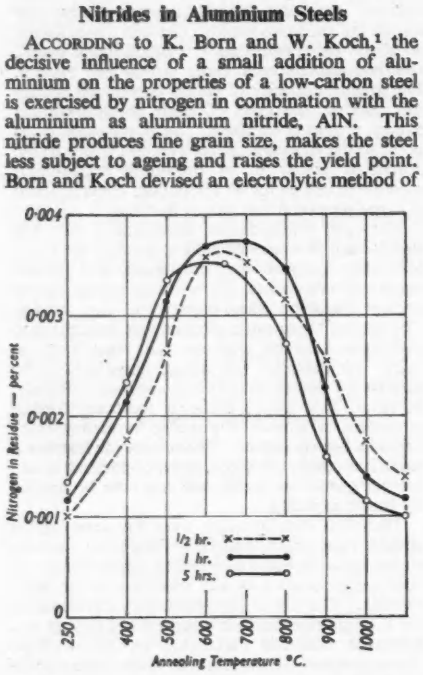


Fig. 1—Nitrogen content in residue separated from steel containing aluminium 0·030, nitrogen 0·005 per cent quenched from 1100 deg. Cent., and annealed for different times at the temperatures indicated (Born)

isolating the insoluble residue from commercial aluminium-bearing steels. When a steel containing 0·005 per cent of nitrogen and 0·030 per cent of aluminium was austenitised at 1100 deg. Cent. and quenched in water, the residue from the steel in the quenched condition contained about 0·001 per cent of nitrogen (calculated on the basis of the weight of the original specimen) as insoluble AlN. Micro-examination of a specimen which had been heated to 250 deg. Cent. showed a small, but distinctly visible amount of precipitated nitride. When the specimen had been heated for from one to five hours at 400 deg. Cent. more than 40 per cent, and at 500 deg. Cent. over 60 per cent of the total nitrogen content was precipitated. The maximum precipitation was nearly 75 per cent after heating at 700 deg. Cent. Differences due to different annealing times were not great, but the maximum was obtained by annealing at a slightly lower temperature if the time of annealing was prolonged. The initial increase and subsequent fall in the value of the maximum is shown in Fig. 1.[2]

It may be recalled that H. F. Beegly[3] first obtained a curve of this type. He described a

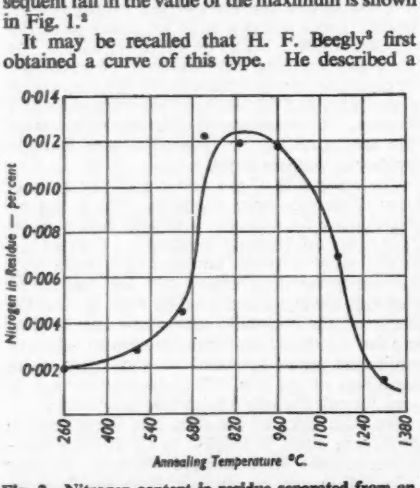


Fig. 2—Nitrogen content in residue separated from an aluminium-bearing steel annealed for one hour at the temperatures indicated (Beegly)

method in which a halogen in an anhydrous organic solvent was used to dissolve the iron matrix of commercial aluminium-killed steels, and showed that the aluminium nitride retained in the residue varied with the thermal treatment of the specimen (Fig. 2). Since aluminium nitride is stable when heated, even in a vacuum, at temperatures as high as 1100 deg. Cent., it was assumed that the fall in the curve at high annealing temperatures was due to the increasing solubility of aluminium nitride in the steel. This is confirmed by the fact that grain-growth inhibition ceases when the aluminium nitride content of the residue has again fallen to a low value. This is clear in Fig. 3, which refers to the same

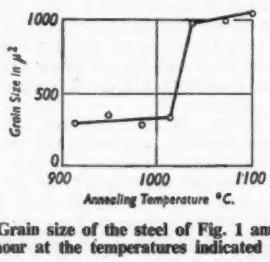


Fig. 3—Grain size of the steel of Fig. 1 annealed for one hour at the temperatures indicated (Born)

steel as Fig. 1, heated for one hour at the temperatures indicated.[2] The fine grain size and tendency against overheating of the aluminium bearing steels is thus dependent on the presence of a fine nitride precipitate.

NITRIDES IN NITRIDED STEELS

A further study of the nitrides in aluminium steels has been carried out by W. Koch, C. Ilschner-Gensch and H. Rohde.[4] Specimens of low-carbon steel with 0·005 to 0·75 per cent of aluminium were nitrided with ammonia for seventeen hours at 600 deg. Cent. and subsequently annealed for forty-eight hours at 1000 deg. Cent. in a stream of ammonia. The structures of the nitrided layers were studied microscopically and the nitrogen distribution determined by microanalysis. The nitrogen-rich layer was characterised by a fine grain size, and contained more nitrogen the higher the aluminium content of the steel (Fig. 4). The depth

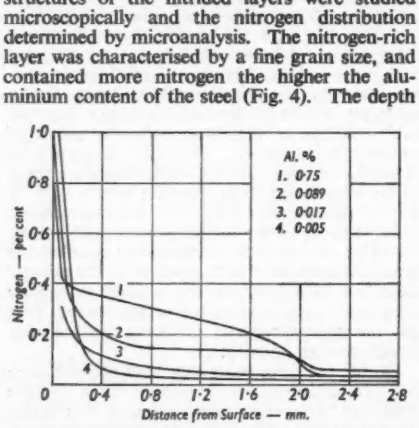


Fig. 4—Comparison of nitrogen distribution in nitrided low-carbon steels with different aluminium contents (Koch *et al.*)

of the nitrided layer as found analytically coincided with the depth of the region of restricted grain growth due to the action of precipitated nitride particles. This precipitate was isolated electrolytically and then studied by microanalysis, X-ray analysis, visual and electron midroscopy and electron diffraction. Besides the known nitrides Fe_4N and Fe_2N in the low-manganese steel with 0·005 per cent aluminium and AlN in similar steels with 0·1 per cent or more of aluminium (the manganese in each case being 0·07 per cent or less), a hitherto unknown cubic nitride with face-centred structure was identified in the nitride residue from steels containing 0·017 and 0·089 per cent of aluminium with 0·36 per cent of manganese. A steel containing 0·099 per cent of aluminium and 0·35 per cent of manganese, but not nitrided, gave only aluminium nitride, AlN. Two commercial nitriding steels containing aluminium 1·0, chromium 1·3 per cent and chromium 1·2, molybdenum 0·19 per cent respectively, were nitrided at 600 deg. Cent. for four hours in ammonia. In the nitrided layer of these steels this cubic nitride was the only nitride phase present. It occurred in the form of thin laminæ only revealed at very high magnification. Its constitution was not definitely established, but it appeared to be a nitride of the general formula M_xN (x being about 1), and that aluminium or chromium played an essential part in its structure.

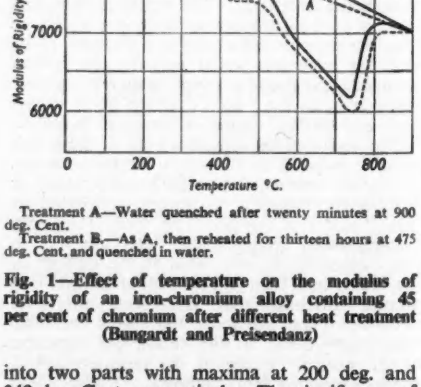
The hardness of the surface layer of nitrided alloy steels is attributed by some investigators to the precipitation hardening effect of a critical dispersion of simple chromium and aluminium nitrides. The fact that a higher nitriding temperature produces a softer case supports this theory. Others contend that the high hardness obtained in nitrided steels containing aluminium and chromium is explained by the formation of complex aluminium and chromium nitrides present as a fine dispersion of ultra-microscopical particles. In view of this difference of opinion it is of importance that the constitution of this new cubic nitride and the part if plays in determining the properties of the nitrided case should be further investigated.

REFERENCES

[1] *Stahl und Eisen*, 1952, Vol. 72, page 1268.
[2] *Archiv für das Eisenhüttenwesen*, November, 1956, page 706.
[3] *Analytical Chemistry* (Washington), 1949, Vol. 21 page 1513.
[4] *Archiv für das Eisenhüttenwesen*, November, 1956, page 701.

Damping Characteristics and Elastic Modulus of Iron-Chromium Alloys

MEASUREMENTS have been made in a vacuum, by K. Bungardt and H. Preisendanz,* of the damping characteristics of iron-chromium alloys with chromium up to 45 per cent. As a result of dissolved nitrogen or carbon, grain-boundary viscosity, deformation and the appearance of the sigma phase, three separate damping maxima were produced at 220 deg., 600 deg. and 720 deg. Cent. In general the effects related to damping were displaced to a higher temperature in iron-chromium alloys than in pure iron. The nitrogen and carbon contents were in some way concerned, but the maxima at 20 deg. and 40 deg. Cent. found in unalloyed iron due to dissolved nitrogen and carbon were not present in the chromium-rich alloys. The effect of cold-working was to split the maximum at 220 deg. Cent.



Treatment A.—Water quenched after twenty minutes at 900 deg. Cent.
Treatment B.—As A, then reheated for thirteen hours at 475 deg. Cent. and quenched in water.

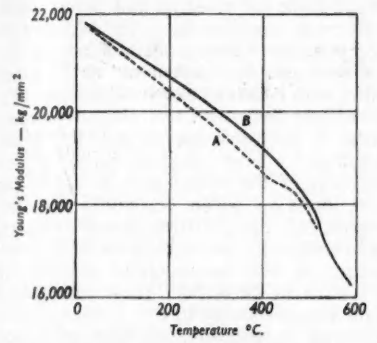
Fig. 1—Effect of temperature on the modulus of rigidity of an iron-chromium alloy containing 45 per cent of chromium after different heat treatment (Bungardt and Preisendanz)

into two parts with maxima at 200 deg. and 340 deg. Cent., respectively. The significance of this is being further investigated.

In the course of these rather extensive experiments, Bungardt and Preisendanz had occasion to measure the effect of temperature on the modulus of rigidity of the 45 per cent chromium

* *Archiv für das Eisenhüttenwesen*, November, 1956, page 715.

iron-chromium alloy. The modulus of the quenched alloy showed a steady fall with increase in temperature up to 400 deg. Cent., when the fall was interrupted and resumed again above 500 deg. Cent. It became increasingly rapid up to 720 deg. Cent., the recrystallising temperature, when a sudden increase in modulus occurred followed by a slow fall above 800 deg. Cent. The minimum modulus at 720 deg. Cent. coincided with a maximum damping capacity. The anomaly in elastic modulus between 400 deg. and 500 deg. Cent. appears to be connected with the " 475 deg. brittleness " which is characteristic of high chromium iron-chromium alloys which have suffered even relatively short exposure to temperatures between 400 deg. and 550 deg. Cent. This brittleness can be removed by heating to 600 deg. Cent. and cooling rapidly ;



Treatment A.—Water quenched from 850 deg. Cent.
Treatment B.—As A, then reheated for ten hours at 475 deg. Cent. and cooled at 1 deg. Cent. per minute.

Fig. 2—Effect of temperature on Young's modulus of an iron-chromium alloy containing 24·7 per cent of chromium after different heat treatments (v. Kienlin)

it exists only after the material has been cooled to 100 deg. Cent. or below. Thus, measurements made on the recrystallised material at diminishing temperatures show a steady increase in modulus (Fig. 1, curve *A*). The same alloy which had been quenched from 900 deg. Cent. and heated for thirteen hours at 475 deg. Cent. showed an uninterrupted steady fall in modulus, giving values almost identical with those of the quenched material at temperatures above 500 deg. Cent. (Fig. 1, curve *B*).

These data were supplemented by A. v. Kienlin† who reported the effect of temperature on Young's modulus of a 24·7 per cent chromium iron-chromium alloy. The water-quenched specimen of this material also showed, but to a lesser extent, a temporary check in the rate of decrease of the modulus at about 450 deg. Cent. If, however, the alloy had been subjected to a preliminary reheating for ten hours at 475 deg. Cent. a smooth curve was obtained (Fig. 2).

In the two examples given, the reduction in modulus over the range room temperature to 600 deg. Cent. is about 22 and 25 per cent, respectively, decreases of the same order as are shown by Armco iron and by austenitic heat-resisting steels.

Modified 12 Per Cent Chromium Steels

CHROMIUM steels containing about 12 per cent of chromium found an early application as steam turbine blades on account of their strength at raised temperatures, their high resistance to corrosion by live steam and their structural stability, which ensured long life. Their creep properties, however, rapidly deteriorated at temperatures above 550 deg. Cent., and their use in highly stressed components was limited to lower temperatures. To meet the demands of higher operating temperatures the 12 per cent chromium steel has been modified by the addition of small quantities of molybdenum, vanadium and tungsten, or molybdenum, vanadium and niobium, or in other ways.

Certain modifications were suggested and reported upon by D. L. Newhouse* and others connected with the Large Steam-turbine Generator Department of the General Electric Company (U.S.A.) in 1954. The structural stability of some of these modified 12 per cent chromium alloys has now been investigated by W. C. Hagel and E. F. Becht.*

Alloy modifications are characterised by the addition of various carbide formers, tungsten, molybdenum, vanadium and niobium, the carbon content being varied accordingly. Carbide-forming elements endow the steel with an improved resistance to tempering, but they may also give rise to detrimental amounts of delta-ferrite and, to avoid this, austenite stabilisers such as manganese, nickel or cobalt are added. Thus, the modification of 12 to 13 per cent chromium steel requires delicate balancing of composition.

The steels examined by Hagel and Becht contained approximately 12 per cent of chromium with percentage additions of either 0·4 Nb ; 2·5 W and 0·2 V ; 5 Co, 3 W and 0·2 V ; 1 Mo, 1 W and 0·3 V ; or 2·7 Mo and 0·25 V ; and with carbon 0·1 to 0·3 per cent, according to the nature of the alloy additions. As a result of increased carbide stability these alloys all exhibited a high rupture strength and resistance to tempering in comparison with the plain 12 per cent chromium steel. In the steel with a niobium addition only, this did not apply to temperatures above 590 deg. Cent. The temperature at which austenite first appeared on heating these modified 12 per cent chromium steels was fairly constant at 815 deg. Cent. The $M_{23}C_6$ carbides dissolved on further heating at about 955 deg. Cent. for the steel containing niobium, 982 deg. Cent. for the 12 Cr-Co-W-V steel, 1038 deg. Cent. for the 12 Cr-Mo-W-V steel, 1093 deg. Cent. for the 12 Cr-W-V and 12 Cr-Mo-V alloys. With one exception, these steels showed stability of structure in prolonged tests. The only one in which marked instability was observed was the alloy containing 5 per cent of cobalt in addition to tungsten and vanadium. This steel, hardened and tempered, showed a separation of chromium-rich ferrite with increase in hardness and decrease in impact value after 200 hours at 480 deg. Cent. After 6000 hours under stress at 510 deg. to 650 deg. Cent., separation of the sigma constituent caused an extreme decrease in impact resistance with no significant increase in hardness. It seems clear that cobalt, so effective in the austenitic heat-resisting steels, is an undesirable addition to the chromium ferritic steels. The results emphasise the importance of carrying out prolonged exposure tests under working conditions before it is possible to obtain reasonable assurance of freedom from deterioration in long-time high-temperature service.

Nitrided Chromium

THERE are certain engineering requirements for materials which resist corrosion at elevated temperatures and maintain a low coefficient of friction between moving parts. Recent advances towards the development of nuclear power for marine propulsion have emphasised the need for materials that can withstand sliding contact in water at high pressure and temperatures of 250 deg. Cent. and over. One method of reducing friction in such circumstances would be by the use at the wear interface of Teflon or some similar polymer in conjunction with a corrosion-resisting material, and this may be the best solution ; but an alternative would be the use of a material giving in itself the characteristics of corrosion resistance, freedom from tendency to galling or seizing, and low wear.

It is claimed by S. W. McGee and C. H. Sump,† of the Armour Research Foundation, Illinois Institute of Technology, that nitrided chromium meets these requirements and that its use is commercially feasible. The wear and frictional properties of a number of materials operating in high-temperature water have already been investigated by R. C. Westphal and J. Glatter‡ by means of wear tests in which the two halves of a split piston are forced against the inner wall of a hollow cylinder by a calibrated spring separating them. During the test the assembly was contained inside a water-filled autoclave at the required pressure, temperature and oxygen content. The split piston was driven in reciprocating motion by means of a shaft passing through a series of seals and alignment bearings. The piston and cylinder were either of the same or of different materials. The outstanding performance of nitrided chromium is illustrated by the figures in Table I. Both nitrided

TABLE I—*Selected Results of Piston-Cylinder Wear Test*

All tests performed at 500 deg. Fah. (260 deg. Cent.) in oxygenated water. Radial load 3 lb. First item is piston. Loss of weight in milligrammes per pound load per million cycles.

Material combinations	Weight loss
Nitrided chromium plate-nitrided chromium...	0·0
As plated chromium-nitrided titanium	4·7
Honed chromium plate-Stellite No. 3	8·3
As plated chromium-as plated chromium ...	32·0
Stellite No. 3-Stellite No. 3	65·0
Stainless, type 304*-Stainless, type 304	3200·0

* Carbon 0·08 (max.), chromium 18–20, nickel 8–10, manganese 2 per cent (max.).

chromium and nitrided titanium had a high resistance to corrosion in heated water. It was found, however, that the depth of hardness penetration in nitrided titanium was insufficient to give consistent results. Some nitrided titanium gave excellent wear resistance, but in others the shallow nitrided layer was disrupted and galling resulted. The depth of hardness penetration obtained in nitrided chromium, on the other hand, was sufficiently great to permit of honing without any loss in resistance to wear. Nitriding experiments were carred out in anhydrous ammonia at temperatures from 540 deg. Cent. upwards on arc-melted chromium, chromium plate and pack chromised surfaces, to ascertain the most suitable treatment. Temperatures involved in nitriding chromium are much higher than those used in nitriding steel. In nitriding the chromium-plated surface of stainless steel it was found desirable to apply a very high-temperature diffusion-bonding treatment to the plated surface before nitriding. It was concluded, in view of the present stage of development, that the ammonia nitriding processes for chromium and chromised surfaces offered great promise towards providing improved materials for heated water service or any similar conditions where inadequate lubrication exists.

Platinum Metals Review

UNDER this title a new quarterly survey of research on the platinum metals and of developments in their application in industry is being published by Johnson, Matthey and Co., Hatton Garden, London, E.C.1. The first number, issued in January, 1957, contains articles on platinum mining in the Transvaal, platinum metals for bursting discs and as catalysts in chemical industry, high-temperature thermocouples, electro-deposited rhodium in radio engineering, the electro-deposition of ruthenium and the creep properties of platinum as well as a comprehensive set of abstracts of current literature and new patents relating to the platinum metals. The use of platinum-clad anodes may help to solve the problem of the cathodic protection of active ships. Platinum and its associated metals have a unique combination of properties which renders them indispensable for many scientific and industrial purposes in the fields of chemistry, metallurgy and electrical engineering. As a source of current information on the properties and applications of the platinum metals the *Platinum Metals Review* is likely to be welcomed by a wide circle of readers.

INSTITUTE OF METALS.—The Institute of Metals is to hold its spring meeting in London, from Monday to Saturday, April 29 to May 4. The meeting will be a joint one with the Associazione Italiana di Metallurgia, the Société Suisse des Constructeurs de Machines, and the Schweiz. Verband für die Materialprufungen der Technik. The programme will include sessions for the discussion of technical papers, visits to works and laboratories, and a banquet. The meeting will begin on Monday evening, April 29, with the delivery of the May lecture, by Sir Eric Ashby, on the subject of " Education in Science and Technology." The annual general meeting of the Institute of Metals will be held on Tuesday morning, April 30, when Dr. L. B. Pfeil, F.R.S., will deliver his presidential address.

† *ibid.*, page 724.
* *Trans. Amer. Soc. Mech. Engineers*, Vol. 76, 1954, page 1107.

* *ibid.*, October, 1956, page 1439.
† *A.S.T.M. Bulletin*, October, 1956, page 58.
‡ *A.S.M.E., Miscellaneous Papers*, 54-SA-13, September, 1954.

LETTERS AND LITERATURE

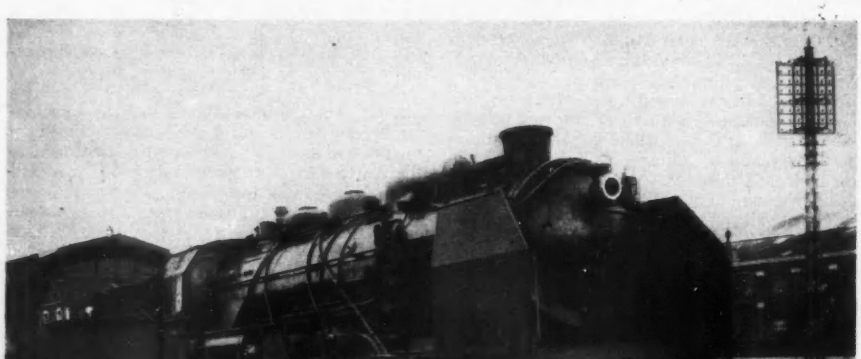
Letters to the Editor

(We do not hold ourselves responsible for the opinions of our correspondents.)

FRENCH LOCOMOTIVE EXPERIENCES

SIR,—You published a letter from me on this subject in your issue of September 14 last. At the time I could not find a photograph suitable for reproduction of the type of locomotive with which Mr. Livesey's article in your August 24 issue was mainly concerned. Now, however, thanks to the kindness of my friend, Baron Henri Petiet, I enclose a photograph of the very machine on which Mr. Livesey rode from Caen to Cherbourg.

This picture illustrates the circular chimney, round-topped firebox, and long, low tender



S.N.C.F. rebuilt "Pacific" locomotive No. 231-561

which I mentioned in my previous letter. I should point out, however, that one of the excrescences on the boiler, that between the second sandbox and the safety valve, is really only a factory chimney in the background !

J. T. VAN RIEMSDIJK

London, N.2.
December 20, 1956.

[With great difficulty we have managed to persuade our photographic retouchers not to remove the interesting excrescence to which our correspondent refers. We feel, nevertheless—so perfectly does it appear to fit on the top of the boiler—that our apologies are due to the manufacturers.—ED., THE E.]

HOOKE'S INVENTIONS

SIR,—In the review of Mrs. Espinasse's recent biography of Robert Hooke, on page 849 of the December 12 issue of THE ENGINEER, you follow the author in stating that he was the inventor of the division plate for gear cutting.

Hooke is generally credited with the invention of the wheel cutting engine for clockwork and his claim is based upon the bald statement by Dr. William Derham in "The Artificial Clockmaker" (1696). As means of dividing and cutting clock wheels existed before Hooke's time, it is difficult to form a clear idea of what his invention consisted. Perhaps the best account in English is to be found in Rees's *Cyclopaedia* (1819), Vol. X, article "Cutting-Engine."

Long before Hooke, division plates with a radial ruler and subsequently a guide for a slitting file, were in use. This is proved by an inventory made in the year 1600 of the tools of Wijbe Wijbrandi, of Leeuwarden. One of the items was :—

"Een mesken ronde teyckenplaet dyenen (de) tot afftekenen van raders met een daertoe dienen(de) linealen."

The wheel blank was stationary and the radial ruler or filing guide was moved round it. Hooke seems to have been responsible for arranging the wheel blank with the division plate to rotate while a circular file (the forerunner of milling cutters) carried in a stationary frame, could be advanced radially towards the blank. An early cutting engine on this plan can be seen in the Science Museum. Whether Hooke suggested circular files is not clear, but the importance of the rearrangement of the parts of the device, transforming it into an "engine," can hardly be overestimated. Hooke's genius shines brightly enough without the added lustre of the invention of the division plate, which was not his.

R. J. LAW, B.Sc.

Churchover, Warwickshire,
December 27, 1956.

Literature

Fixed Capacitors: Radio and Electronic Components. Vol. III. By G.W. A. DUMMER. Sir Isaac Pitman and Sons, Ltd., Pitman House, Parker Street, Kingsway, London, W.C.2. Price 45s.

THE energetic Mr. G. W. A. Dummer, who is responsible for research and development of electrical components at the Ministry of Supply Radar Research Establishment, has now produced his third book in the series dealing with radio and electronic components. The volume deals with that ubiquitous component in electronic apparatus—the "Fixed Capacitor." Five chapters (Nos. IV to VIII) out of the eleven discuss briefly the main forms in which capacitors are constructed, not in a fully comprehensive manner, but in a way adequate to indicate the essential features of the constructions peculiar to each different dielectric. These descriptions relate almost entirely to the forms currently employed in telecommunication and electronic apparatus generally; but in this respect the title of the volume without qualification might perhaps have been expected to embrace a rather wider sphere of capacitor forms and uses.

Much of the subject matter has been built around the British Joint Services Specifications, and substantial parts of both Chapters I and II are devoted to listing these and other related specifications, including also some in use in U.S.A. and Canada. Chapter II further includes some useful tables of permittivity and other properties of the commoner dielectric and impregnating materials used in capacitors, although there are some notable omissions in this latter part. Another table gives similar data for about a dozen of the more frequently used plastic insulating materials. Other matter is also included in this chapter on the relative properties of the complete capacitors made up with these various dielectrics—properties which may and often do differ materially from the ideal properties of the dielectric.

Measurements on capacitors are discussed in Chapter III, ranging from the early Carey-Foster capacitance bridge, to the Schering and transformer bridges and the twin-T network for use at the higher frequencies. For the u.h.f. frequencies coaxial line wave guides and resonant cavity measurements are briefly discussed, while the remainder of the chapter covers the measurement of the temperature-coefficient of capacitance, a very important property for capacitors used in electronic apparatus of small dimensions where the temperature rise may be high.

Chapters IX, X and XI are rather unusual, but especially interesting from the practical point of view. The experimental types of capacitor described in Chapter IX give a useful picture of the directions in which developments may proceed—at least from the viewpoint of the research establishment—as also do the notes on possible future developments which comprise Chapter XI. The three and a half pages comprising Chapter X describe a few of the troubles that sometimes arise either from faulty manufacture or from misuse of capacitors, such, for example, as "flutter" in types having metallised electrodes with some

imperfections, and "internal-discharges" which may arise from the application of excessive voltages to a capacitor.

In addition to a brief bibliography and a reasonably comprehensive index, a very extensive catalogue of many of the commercial forms of capacitors on the market at the time of preparation completes the book. This catalogue is in tabular form under the R.C.S.C. style numbering, but is a trifle confusing to use, since the width of the table occupies the width of six pages of type setting.

The table gives the mechanical dimensions, the electrical characteristics and the performance of the capacitors judged by humidity resistance, maximum operating temperature and the capacitance stability during working life and shelf-life. A series of one, two or three stars is used in each of these columns to give at a glance a broad picture of the general performance that is currently expected. The value of such an extensive tabulation is somewhat open to doubt, since the British Joint Services "RCL" lists for each of the forms of capacitor taken in conjunction with the relative "RCS" specifications already include all the basic information, which is liable to change often at short notice.

The style of writing is easy and the presentation is good, while only a very few misprints have been noticed. It is perhaps a pity that the book has been virtually confined to "RCS" type-approved capacitors, since there are others used commercially that possess merit. It should be pointed out that commercial equipment is not necessarily built to stand less stringent conditions than the Services needs, as the Preface seems to imply, and trouble-free performance over many years is generally *sine qua non*. Certain minor errors and loose or possibly misleading statements have been noted and it is felt that they should be amended for another edition.

As a companion volume to the two preceding and as a reference book, especially for many users of electronic apparatus, who are often quite unfamiliar with the mysteries of capacitor constructions and performance, the book should be particularly attractive.

Power Production: The Practical Application of World Energy. By Dr. HANS THIRRING. George G. Harrap and Co., Ltd., 182, High Holborn, London, W.C.1. Price 25s.

IN this book, Dr. Hans Thirring, Professor of Physics at Vienna University, makes a courageous attempt to survey in one volume of just under 400 pages the world's energy resources in relation to their past, present and future utilisation. The book is divided into two sections, the first of which occupies about one-third of the text and is devoted to the engines used for power production. This section describes the theory and practical application of the principal types of prime mover, i.e. the steam engine, the internal combustion engine and the gas turbine; it then deals with the heat pump and finally electricity, which, incidentally, is treated comprehensively in one chapter of thirty pages.

The remainder of the book is concerned with sources of energy. After discussing the fossil fuels, their origin, preparation, economics and expectation of life, the author turns to the recurrent sources of energy, i.e. fuels from vegetation, water power, solar energy and, finally, atomic energy, which occupies nearly half of this section. It is predicted that at some time in the twenty-first or twenty-second century the reserves of fossil fuels will be depleted after being progressively replaced by atomic energy and that, in the meantime, coal will have been conserved for utilisation partly by conversion to liquid fuel and partly as a raw material for the chemical industry.

The range of readers for whom the book is intended is almost as wide as the scope of the book itself. They include students and economists, technicians, industrial planners and the general reader. From this it might be inferred that the book is just one more of those pseudo-scientific and rather superficial volumes which are so popular at the moment. Such, however, is not the case. It can be regarded as a serious attempt to survey and put into proper perspective the present outlook on a matter of world-wide importance.

Although the author writes in an easy conversational style, he does not sacrifice scientific accuracy by over-simplification, and he builds up his overall picture from sound first principles. A noteworthy feature is the way in which he manages to illustrate each theme with items of interest to all types of reader, including the specialist. Thus, the mechanical engineer might skim through the section on prime movers, but he would probably pause to look at the details which are given about early types of engine, and read carefully other chapters such as those dealing with solar energy and atomic energy.

Inevitably, some relevant information is lacking. The efficient combustion of coal is considered mainly in terms of the domestic fire, to the exclusion of industrial uses, and although the steam reciprocating engine, and the steam turbine are discussed in detail, steam boilers are barely mentioned. Space is devoted to underground gasification in the U.S.S.R., but not to the experiments in the U.S.A. or in this country. In general, Dr. Thirring has written the sort of book which most of the readers he has in mind could read steadily through and find much of value. It is also one which most engineers could open at random and find something to interest them.

Elasticity, Fracture and Flow, with Engineering and Geological Applications. By J. C. JAEGER. Methuen and Co., Ltd., 36, Essex Street, London, W.C.2. Price 10s. 6d.

IN this slim volume Professor J. C. Jaeger, of the Australian National University, has presented a concise account of the general three-dimensional analysis of stress and strain at a point (or in homogeneous stress and strain), the general equations of motion and equilibrium and the behaviour of actual materials, both solid and liquid, when caused to deform. The treatment of the analysis of stress and strain is sound, in that the author has clearly shown that the analysis of stress is a branch of statics and that of strain a problem of geometrical relations between co-ordinate displacements. All too often in textbooks these fundamentals are blurred by the introduction at the outset of the Hookean relationship between stress and strain. The analysis of strain is dealt with in the generalised form of large (finite) homogeneous strains in three dimensions, infinitesimal strains being introduced as a special case of the general theory. The chapter on the elastic, plastic and fracture characteristics of actual materials is tackled from a mathematical standpoint and, while the chapter on the equations of motion and equilibrium sets out the essentials with commendable conciseness, the typical problems solved are perhaps a little academic. Viscous materials receive brief treatment.

Altogether, Professor Jaeger has produced a very useful statement for anyone having some prior knowledge of stress analysis. The approach is essentially that of a mathematician, and this would hardly be a suitable starting point for the engineer who needs a systematic textbook of instruction. He wants a more graphical approach particularly in three dimensions, where he is more at home with a geometrical representation than a mathematical equation. But as a systematic account of the governing equations and as a ready source of reference, Jaeger's book can certainly be recommended. The author wisely refrains from dealing in detail with applications and problems, which can be found in a host of textbooks, so that his book should be equally useful to all fields of study concerned with the solution of non-uniform distributions of stress and strain. The print and mathematical symbols are clear and attractively presented.

Properties of Combustion Gases. General Electric Company. McGraw-Hill Publishing Company, Ltd., 95, Farringdon Street, London, E.C.4. Price (two volumes), 562s. 6d.

THE aircraft gas turbine development department of the General Electric Company, Cincinnati, Ohio, has computed for C_nH_{2n} burning in air exact values of the properties of combustion gases. The source data were the National Bureau of Standards values for the pure constituents, and mechanical computation has retained the same order of accuracy, usually five significant figures. The first volume, "Thermodynamic Properties," gives values of enthalpy, entropy, mean molecular weight, density, speed of sound (on both equilibrium and "frozen" chemical composition bases), heat capacity, and two functions of the non-ideality of the gases

$$\left(\frac{\partial \log m}{\partial \log T}\right)_p \text{ and } \left(\frac{\partial \log m}{\partial \log p}\right)_T :$$

independent variables are temperature from 2500 deg. R to 5000 deg. R, fuel/air equivalence ratio R from 0·25 to 4·0 in increments adjusted to the degree of non-linearity, and pressure from 0·01 to 30 atmospheres (low temperature properties from 600 deg. R to 2400 deg. R are given for $R=0{\cdot}25$ and $p=0{\cdot}01$). Enthalpies are "absolute" and therefore appear negative at temperatures below the equilibrium state for a given R and p. The second volume, "Chemical Composition of Equilibrium Mixtures," gives the equilibrium composition of the mixtures over the same range of parameters, and tables of enthalpy, Gibbs free energy, entropy and heat capacity for the pure constituents above 600 deg. R. These tables distinguish between mol fractions less than 1×10^{-9} and those identically zero. There is a brief text devoted mainly to interpolation and methods of applying the tables.

Books of Reference

Year Book of the Heating and Ventilating Industry. Technitrade Journals, Ltd., Carlisle House, 8, Southampton Row, London, W.C.1 Price 10s. 6d.—The tenth edition of this reference book, which has been compiled in collaboration with the Association of Heating, Ventilating and Domestic Engineering Employers, contains trade and technical information for architects, consulting engineers, surveyors and others whose work brings them in touch with heating and ventilating contractors. A particularly useful section is the "Literature Index," wherein references are given to items of special interest to the heating and ventilating industry; they are drawn from the publications of technical societies and institutions. Special articles this year include "Oil-Fired Air Heaters," by J. Langford; "Panel Heating," by H. H. Bruce; and "Electric Surface Heating of Fuel Oil Lines and Storage Tanks," by H. Reik.

Two Colliery Reorganisation Schemes

No. 1

The recent publication of "British Coal; the Rebirth of an Industry," marked the completion of the first ten years of public ownership of the mines of this country. It is pointed out that under the 1950 plan it was proposed to remodel some 250 collieries and that work is in hand on no less than 180 projects. Two reorganisation projects which were in hand before the plan was produced are those at the Bradford colliery, Manchester and the Bold colliery, near St. Helens, Lancs. The first of these projects is in an advanced state and the second has just been completed. Some impression is given in this article of the great amount of work entailed in planning and carrying out such extensive reorganisation schemes.

ALTHOUGH vast sums of money have been spent in recent years by the National Coal Board on reorganisation and modernisation schemes at collieries throughout the country, relatively little is known generally of the work of interest to engineers which has been, and is being done. This is probably because many of the schemes involve much long-term planning and take a number of years to become fully effective, by which time those primarily concerned are too fully engaged on other projects to consider further that which has already been achieved. For this reason we were particularly interested when in the course of a visit to the Manchester offices of the North-Western Division of the National Coal Board we heard of two extensive colliery modernisation schemes which are well worth putting on record. The first of these schemes concerns the reorganisation of the Bradford colliery situated in Manchester city area, which is now in its final stages after about eight years' work; the second scheme is that recently completed at the Bold Colliery in the St. Helens area, which was started in 1949.

Reorganisation of Bradford Colliery

A scheme for the reorganisation of the Bradford Colliery was started by the owners, Manchester Collieries, Ltd., before the coal mines of the country were nationalised, and this work was continued and the original plans extended by the National Coal Board. The colliery lies within the Manchester city boundaries and its surface site covering only 5 acres is situated in a densely built-up area. The congested surroundings have throughout the scheme caused particular difficulties, and, as production had to be maintained, much of the building has had to be done piecemeal by tearing down old structures in parts as new erections proceeded. It was estimated that there were some 275 million tons of coal available in the mine, and it was decided that by modernisation and re-equipment the output could be increased to 2000 tons of coal a day with single-shift working or 4000 tons with two-shift working. An important part of the scheme has been the delivery of the ¼in part of the output directly by an underground conveyor system to the Stuart Street power station about 600 yards away from the colliery. The remainder of the output is taken away by road vehicles from a new loading depot.

The colliery had two main shafts, No. 1 (Deep Pit) being used for all winding and No. 2 (Parker Pit) being used for ventilation, manpower and materials. It was decided to install skip winding gear at No. 2 upcast shaft with a Koepe winder at ground level, whilst the No. 1 shaft would be equipped with a clutch-driven winder for raising and lowering men and materials in the mine. Under the scheme it was proposed to continue coal winding at No. 1 shaft and to transfer coal winding to No. 2 shaft when it was ready and whilst the No. 1 shaft was rearranged and its new winders installed. The reconstruction and re-equipment work at No. 2 shaft has now been completed and work is in progress at No. 1 shaft. Other work involved the installation of ventilating equipment, coal preparation plant, bagging plant, raw coal emergency storage, dirt handling and crushing plant, compressor plant, substation, and a conveyor to the Stuart Street power station.

The first work undertaken was at the No. 2 upcast shaft, where a 200ft high Koepe tower had to be built for winding the coal in 12-ton skips from a depth of 943 yards at a rate of 350 tons per hour. To provide for the new installation the first work entailed the replacement of the original brick lining of the shaft to a depth of 60ft below the surface with a reinforced concrete lining. A temporary steel headframe was built on this lining to provide the necessary emergency winding facilities, and at a later stage this headgear was removed and installed on the first floor of the Koepe tower. Before demolition of the existing headframe and fan house at this shaft it was first necessary to install a new mine fan to maintain ventilation. A further complication was that an air seal had to be maintained at this upcast shaft throughout the work and, as it provided the second mine exit, winding facilities had also to be retained. The new fan drift was incorporated in the tower foundation and when the tower was completed up to the first floor an exit for men provided in this drift was arranged as an air seal. At the same time the completed first floor was used as a support for the temporary headsheave for winding.

The three-stage axial flow fan installed by Aerex, Ltd., has a capacity of 120,000 cubic feet per minute at 4in water gauge. It was initially driven by a 150 h.p. motor, which was later replaced by one of 475 h.p. to give a capacity of 200,000 cubic feet per minute at 8in water gauge. In order that this fan could be used in service whilst the tower foundations were under construction a section of its drift passing through the foundations was made temporarily in steel. The permanent drift which is integral with the tower foundations was built round this steel casing, which has now been removed. The new fan house is situated below ground level and its roof, supported on reinforced concrete beams, incorporates removable slabs which will give ease of access when it is necessary to remove or install plant. A second fan house is at present under construction.

Work is now in hand at No. 1 shaft, where a new headgear and winding equipment is being installed. While this work is going on the original wooden headgear and steam winding plant are being kept in service. A new winder house has been completed, and the double-drum winder supplied by Vickers Armstrongs, Ltd., and driven by two 850 h.p. Metropolitan-Vickers motors being installed, can be seen in Fig. 1. To avoid interference with production as far as possible, the steel headgear for the new winding equipment has been built round and over the original wooden structure, as shown in Fig. 2, without interference with the steam winding plant. This steam winding plant can be seen on the right in our illustration with the temporary backlegs of the new headgear extending down towards its walls. The concrete structure under construction on the left of the headgear is a new dirt storage bunker, and the new winder house is situated on the left beyond this bunker. The bunker structure incorporates footings for permanent backlegs of the new headgear, which will be installed upon its completion. The condition of the original mine plant can be appreciated from the part of the steam winder plant boiler house to be seen on the left of the new Koepe house in Fig. 1. When the new equipment goes into service the old boiler house will be demolished and the new mine workshops will be extended to cover its site. A part of this workshop was built at an early stage in the reorganisation and has been in use for some time.

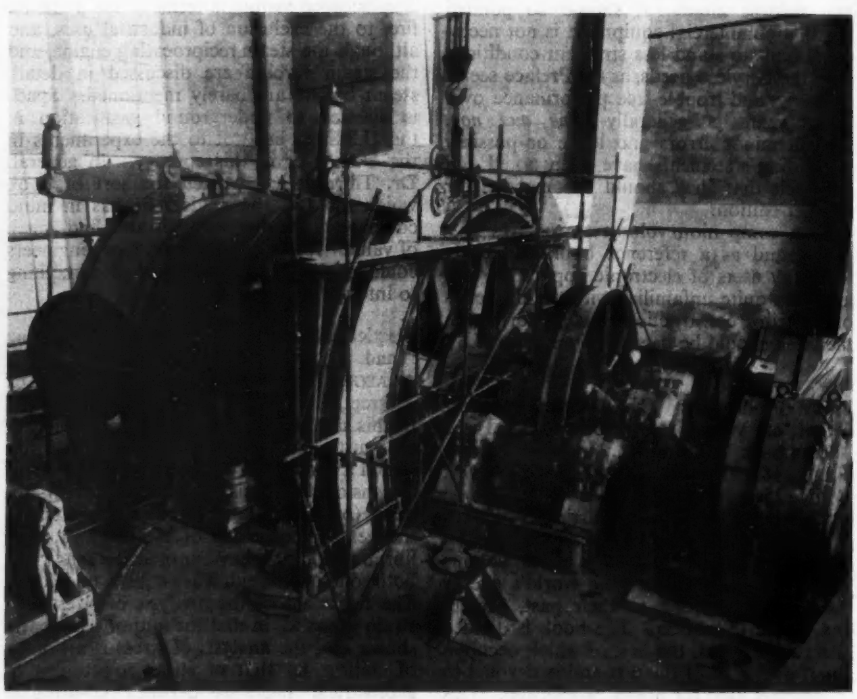


Fig. 1—Double-drum winder for No. 1 shaft being installed in the new winder house at Bradford colliery

The reinforced concrete tower at No. 2 shaft, which has been built for the Koepe winding plant by A. Monk and Co., Ltd., to the designs of the British Reinforced Concrete Engineering Company, Ltd., can be seen in one of our illustrations (Fig. 3). It has an overall height of just over 200ft. and its lower part is built into one end of the main structure of a winder house, which is 55ft high by some 113ft long and 50ft wide. Two 24ft diameter winder wheels are mounted in the upper part of the tower and air-

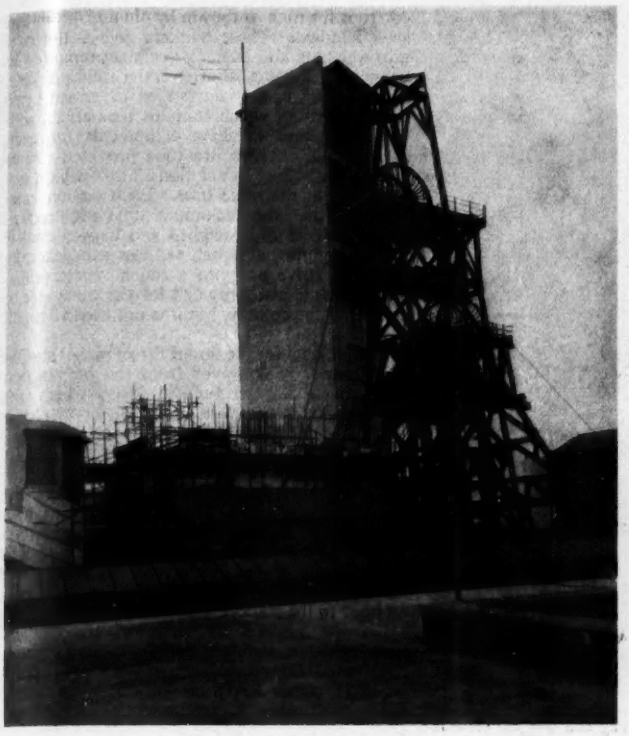


Fig. 2—New steel headgear for No. 1 shaft under construction round the original wooden headgear whilst it remains in service. The Koepe winder tower for No. 2 shaft can be seen behind the steel headgear

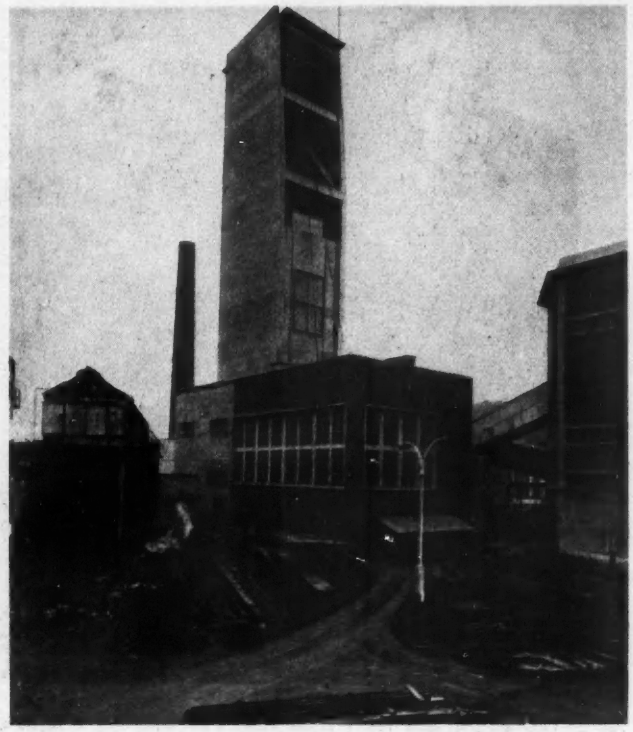


Fig. 3—New reinforced concrete tower and winder house for Koepe plant at the Bradford colliery No. 2 upcast shaft. This tower is over 200ft high and the fan drift is integral with its foundations

locks provided in its lower section are capable of passing mine cars or skips.

The ground-mounted Koepe winding plant, supplied by the Metropolitan-Vickers Electrical Company, Ltd., and the Fraser and Chalmers Engineering Works, is designed for an output of 400 tons an hour when winding from depths of 2802ft, 3312ft and 3822ft respectively. A supplementary capstan winch of 300 b.h.p. in the base of the tower used in installing and changing the winder rope is adapted for use as an auxiliary winder when carrying out shaft repairs. The interior of the winder house can be seen in Fig. 4 and in it the main 24ft diameter winder wheel is driven through a single reduction double helical gear by two 1860 h.p. d.c. motors. This equipment has a winding cycle of 108 seconds, which enables thirty-two winds per hour to be made.

Coal is raised by two bottom-opening, 12-ton capacity skips and at the top of the shaft these skips move in guides rigidly supported in a steel structure built up through the lower floors of the winder tower. The skips are each 12ft long by 4ft wide and weigh 14·5 tons. They are set at 5ft 6in centres on fixed guides in the 18ft diameter mine shaft.

The skips are loaded by plate feeders via measuring pockets in the mine, and at the top they are discharged into 12-ton hoppers situated below the discharge floor of the tower. When an ascending skip reaches its unloading level at the surface its guillotine door is opened by compressed air operated cylinders, permitting the discharge of the coal into a receiving hopper. Each hopper is fitted with a top and bottom air-lock door which is interlocked so that only one door can be opened at a time. These hoppers discharge into chutes leading out from the side of the tower to 5ft wide plate belt conveyors feeding the coal preparation plant. This plant is designed to handle 350 tons of coal an hour as follows : 8in by 1in in a Tromp washery supplied by Birtley Company, Ltd., 1in by $\frac{1}{8}$in in a Baum washery supplied by Simon-Carves, Ltd., and $\frac{1}{8}$in to 0in uncleaned.

The run-of-mine coal is delivered to two 48in wide troughed belt conveyors running at 250ft per minute and discharging on to primary screens, where it is separated into plus 6in, 6in by 2in and 2in by 1in. The plus 8in raw coal is collected from the primary screens by a 28in wide picking belt. Large pieces of dirt are removed at this stage and deposited through chutes to a concrete hopper ; the large coal passes on to be reduced by pick breakers and rescreened.

From the primary screens the 8in by 1in raw coal is discharged directly into two Tromp baths, and after washing and dewatering this coal is delivered by a conveyor system to the bagging plant, where it is screened into 8in by 4in and 4in by 2in and stored in hoppers. The dewatered 8in by 2in refuse from the Tromp section is crushed to 2in and delivered by belt to the mine refuse distribution system. The middlings from the baths are cleaned and dewatered before being crushed to $\frac{3}{4}$in. The 1in by 0in raw coal from the primary screens is taken to Baum wash boxes, cleaned, dewatered and conveyed to the power station conveyor. The fines are recovered from a thickener and filtered, after which they are mixed with the $\frac{3}{4}$in to 0in product.

An essential part of the reorganisation scheme was the provision of adequate storage facilities for run-of-mine coal on the surface in case of a breakdown in the preparation plant. For this purpose hoppers with a capacity of 1100 tons have been built on the side of the preparation

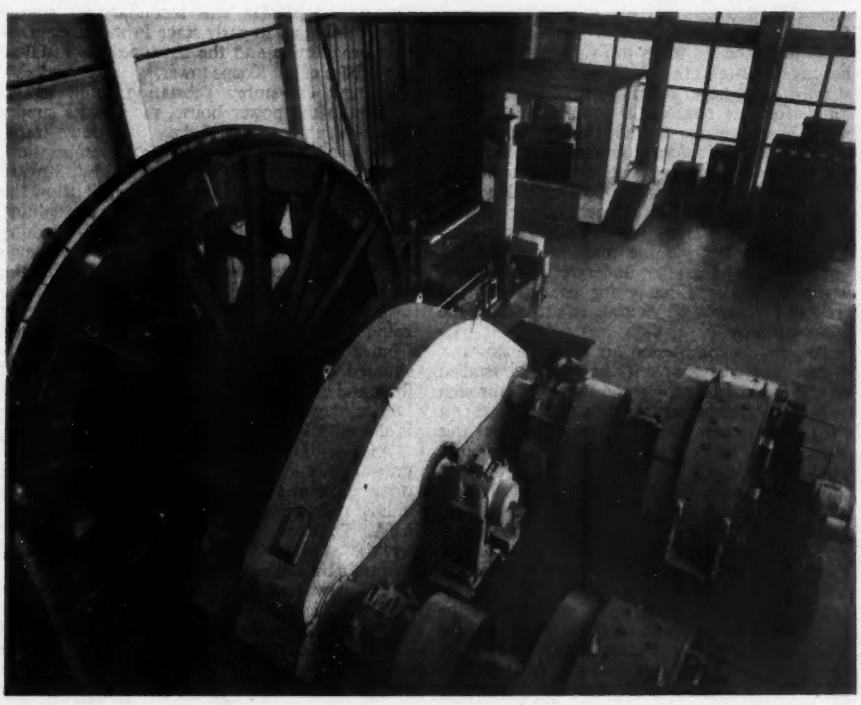


Fig. 4—Ground mounted Koepe winding gear for No. 2 shaft. This 24ft diameter winder wheel is driven by two 1860 h.p. motors

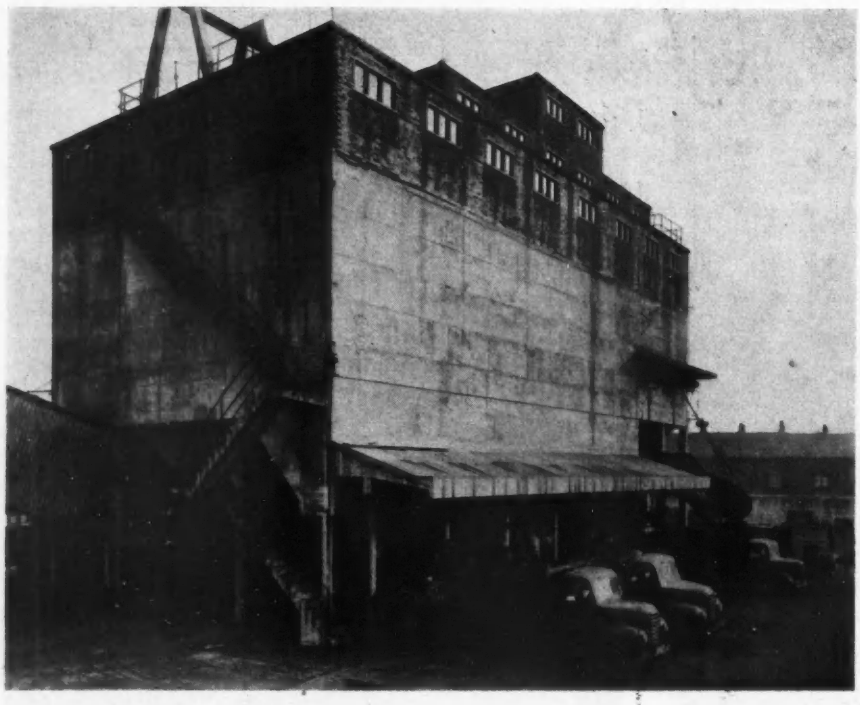


Fig. 5—Coal bagging plant with overhead bunkers delivering coal to twelve weighing and bagging stations on a lorry loading wharf below

plant house and there are also two 100-ton capacity emergency storage hoppers in the house itself. Additional capacity in other sections of the mine brings the total storage capacity to 2000 tons. Suitable provision has been made in the coal handling plant to divert the raw coal into the storage hoppers, and for its return to the cleaning system at a rate of 200 tons an hour from vibrating feeders at the bottom of the hoppers.

A comprehensive dust collecting system in the preparation plant maintains a high standard of atmospheric conditions throughout, and all the dust collected is mixed with the washed coal delivered to the power station conveyor. There is also a market for dry air-borne dust, and the whole of the discard from the plant is collected and delivered to the main storage hopper for use in mine stowage.

As the mine workings are situated beneath a heavily built-up area, a system of pneumatic stowage has been installed, and as sufficient refuse for this purpose is not available at the mine, a scheme for the handling of up to 100 tons per hour of refuse from elsewhere has been installed. This refuse is delivered to the site by road and after crushing and screening is deposited into a 1000-ton storage hopper by a system of belt conveyors. The refuse is loaded into mine cars for delivery via the main winder to the upper horizon in the new underground workings, where it is stored ready for use. A further crusher for stowage materials is situated in the mine workings.

To provide compressed air for mine stowage, a new compressor plant has been installed on the surface to supply the workings through a 16in air main situated in the No. 2 pit shaft. The new building required for this plant had to be built in two stages in order that production should not be affected. In the first stage an existing building and part of the old mine offices were demolished to provide a clear site and a section of the building sufficient to accommodate two compressor sets was erected. The building was completed later and the other sets required were installed.

Dirt stowage normally takes place during the night shift in the mine, and in order to take advantage of the power factor correction capacity of the synchronous motors used to drive the compressors, provision is made for declutching the motors so that they can be run as synchronous condensers during the day shift. Normally two compressors provide sufficient air and the third set is used as a stand-by. These three turbo-compressors, supplied by the Metropolitan-Vickers Electrical Company, Ltd., each have a capacity of 7500 cubic feet per minute at 80 lb per square inch. They are single flow, multi-stage machines driven by 2000 b.h.p., 1000 r.p.m. motors through gearing at 7500 r.p.m.

During the day shift a supply of compressed air is required for operation of the skip loading and discharging equipment and for the coal preparation plant. The amount of air required for these purposes is insufficient to justify the use of one of the main compressor sets, so another set of 750 cubic feet per minute capacity has been installed. This set delivers air at 80 lb per square inch via a receiver to the winder tower and pit bottom for skip operation ; and also to the coal preparation plant. This secondary air supply was required at an early stage in the reorganisation programme and the machine was installed in the base of the Koepe tower.

A new two-storey substation, built as an annexe to the power house, receives its supply at 6·6kV, three-phase, 5 d.c. Step-down transformers at ground level, under the substation, provide the mine with 3·3kV and 800V, 3-phase supplies. Also housed on ground level below the building are two lighting transformers, a lighting distribution board, a neutral point earthing cubicle for the transformers and a battery charging plant for the 6·6kV switchgear. On the first floor of the building there is situated the 6·6kV and 3·3kV switchgear ; the 6·6kV gear being 350MVA capacity and remotely operated from a control room. The 550V switchgear is situated on the coal preparation plant ground floor and contactor gear is situated on each floor. During the day shift the load on the substation is about 7000kVA at 0·95 power factor.

As already mentioned, one of the main compressor motors can be disconnected from its drive and run as a synchronous condenser providing up to a maximum of 1400 leading reactive kVA. The excitation of this machine is controlled by the substation attendant, who is able to maintain the colliery power factor at 0·95.

The new coal screening and bagging plant (Fig. 5) which has been laid down near the main surface workings is supplied from the preparation plant by an overhead belt conveyor. It is designed for the bagging of 8in by 4in and 4in by 2in coal as well as loose loading, and bunker capacity is provided for smaller sizes for delivery by road or rail. The coal is delivered to overhead bunkers with a total storage capacity of 400 tons for each of the 8in by 4in and 4in by 2in sizes handled. These bunkers deliver the coal into weighing and bagging machines mounted in pairs on a loading wharf for the road vehicles. This loading wharf is arranged to provide two sections each of which contains six stations with bag filling and weighing equipments for each size of coal. There are thus provided twelve weighing and bagging stations, all of which can be in use at the same time. Each station is so designed that the maximum time required to load a vehicle with weighed and bagged coal is twenty minutes, although vehicles can generally load and drive away in a much shorter time. Rail access is also provided for the transport of coal from the colliery, but it is not used to much extent.

The ¾in coal for the Stuart Street power station is delivered by conveyor from the preparation plant to a 500-ton bunker, from which the coal gravitates down into the feed hopper of a belt conveyor some 150ft below ground level. This belt conveyor runs in a 450 yards long tunnel beneath a residential area to the site of the power station. At the far end of the tunnel the coal is transferred on to an inclined belt which carries it up for delivery into either a 1100-ton storage bunker or a stock yard. This conveyor system incorporates weight-recording equipment and is designed to deliver up to 200 tons of coal an hour to the station.

On the underground side of the colliery reorganisation, standard horizon mining practice has been followed, using two horizons—No. 1 being 727 yards deep and No. 2 being 897 yards deep—and other horizons will be developed later. During the initial stages of development the areas to be worked are to the north and to the west of the colliery. Access to these areas is provided by the two horizons, which are 170 yards apart, and to facilitate the working of the coal in the west a staple shaft has been raised from the lower to the upper horizon. The lower horizon has been driven from the existing shaft bottom, and the position of the upper horizon has been fixed so as to give a life of thirty years between the two horizons in both areas.

In the west the basin-like structure of the field is such that the position of cross-cuts, other than the first one, will be influenced by the distance the faces can be taken from the first cross-cut without undue cost in repairs, by the effect of small faults, and by the change in the direction of the line of strike. On the north, the initial development will be made from two cross-cuts which have been driven directly into the area from the shafts. Here it will be necessary to open out in both directions away from the main cross-cuts by driving laterals at both horizons. The positions of the additional cross-cuts will depend on the length of time the roads will stand and on the conditions found in the area. The staple pits will be raised as required and, where necessary, intermediate horizons will be used. The faces will be worked in strict sequence, using four faces per cross-cut. The main lateral of the No. 2 horizon has been driven in fairly strong ground and to date 5500 yards of tunnelling have been completed at this level.

The No. 1 horizon will be used to receive all dirt for pneumatic stowage, which will be crushed and loaded into mine cars for transport to the staple shafts. These shafts will be rectangular in shape, 12ft 10in by 10ft 5in, and will be equipped with spiral chutes having an automatic exit section at the bottom for feeding into a shaker chute, loading directly into mine cars. To date about 6350 yards of tunnelling have been completed at this horizon.

(To be concluded)

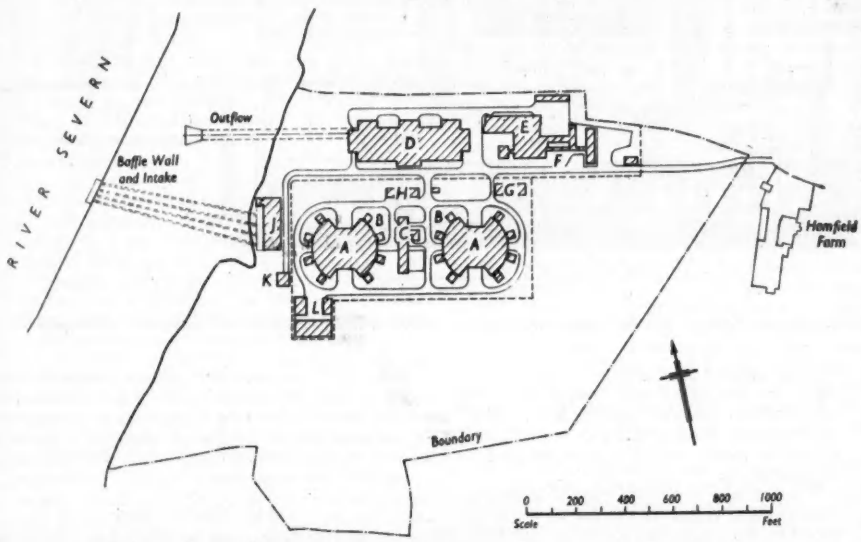
INTERNATIONAL CONFERENCE ON PRESTRESSED CONCRETE.—An international conference on prestressed concrete is to be held in San Francisco, California, from July 29 to August 2, 1957. It is being organised by the University of California in co-operation with the Fédération Internationale de la Précontrainte and the Prestressed Concrete Institute of America. Papers on research, design and construction of prestressed concrete are invited for presentation at the conference. Further information may be obtained from the department of conferences, University of California, Berkeley, 4, California, U.S.A.

Berkeley Nuclear Power Station

In our issue of December 21, 1956, page 891, we referred to the placing of contracts for the first three of Great Britain's nuclear power stations. We have now received a few more details of one of these stations—that at Berkeley, Gloucestershire, and they are included in the following description which outlines the arrangement of the station.

THE nuclear power station at Berkeley, Gloucestershire, will occupy part of a 96-acre area site on the Severn Estuary, and is designed for base load operation and an output of 275MW sent out. The main plant installation will consist of two natural-uranium, graphite-moderated reactors, each cooled by eight pressurised CO_2 gas circuits comprising heat exchangers and gas circulators. Steam generated in the sixteen heat exchangers will be used to generate electricity in four turbo-generators of about 80MW capacity.

As may be seen from the accompanying site layout plan, the basic design for the station is determined principally by the relationship of the three major units, namely, the turbine house and the two reactors. These units are arranged symmetrically about a centre line, and the smaller ancillary units are close to the main units to suit the functions of the various buildings and to facilitate movement from one to the other.



A—Reactors. *B*—Heat exchanger. *C*—Cooling pond. *D*—Turbine hall. *E*—Workshop. *F*—Canteen. *G*—Fuel element store. *H*—CO_2 store. *J*—C.W. pump house. *K*—Sewage works. *L*—Active waste treatment.

Site layout of Berkeley nuclear power station, Gloucestershire. The station is designed for a net output of 275MW

All the buildings are grouped as closely as possible to each other to provide maximum economy of roads, surface lines, personnel movement and site filling, but allowance has been made for the difficult access problems which the speed of construction programme will create. The site is separated by an " active area fence " into two distinct areas. The first encloses those buildings which are connected with the nuclear portion of the station, and the second encloses the conventional power station buildings—that is, turbine hall, administration block and workshops.

Within the active area there are two reactor units with associated irradiated fuel storage pond, decontamination building and active laundry. Access to this area is through a security gatehouse control point situated at the centre of the site. Within a very short distance of this point is the main control centre in the turbine hall. A uranium fuel store building is provided within the inner fence, but deliveries by road may be made through a special gate from the inactive area so that vehicles need not enter the active area. The axis through the turbine hall and between the two reactors is roughly parallel to the River Severn. The cooling water pumphouse is near the river bank, and the administration, workshops and general welfare block is away from the river and overlooking the approach road into the site.

This road gives access to the centre of the site, to all buildings and to the active area. A service road running parallel to the main road leads to the rear of the administration unit and the main loading bays of the turbine hall, and to the main transformers. The active area is served by a ring road which has a lay-by to each important access point.

Reactor

Each reactor core will consist of a vertical cylinder about 48ft diameter by 30ft high, constructed of graphite blocks and containing about 3000 vertical channels for the fuel elements. A cylindrical pressure vessel about 50ft diameter by 80ft high, made of 3in thick steel, will enclose the core, and will be surrounded by thermal shielding of 4in steel plate and a concrete biological shield about 8ft thick. The fuel elements will be made up of uranium rods just over 1in in diameter, sheathed in finned magnesium alloy cans. They will be individually supported in the channel to overcome the effects of creep which would result if the elements were stacked one on the other. The length of the elements will be such that creep occurring due to their own weight will be negligible. A simplified section through the reactor is reproduced overleaf.

Graphite Moderator.—The design of the graphite moderator is generally based on that developed by the United Kingdom Atomic Energy Authority for the Calder Hall power station. Accordingly, the moderator will be built up of a large number of individual vertical columns of graphite bricks and tiles, each column being 30ft high and individually supported through a ball bearing assembly on cross braced girders. These girders will transmit the weight of the structure to the " A " frames supporting the reactor pressure vessel. The complete assembly will form a thirty-two-sided regular polygon prism with a vertical axis. Provision is made in the design for Wigner growth and expansion movement generally, equipment being included for initiation and control of periodic Wigner energy release operations.

Throughout the life of the reactor the geometry and stability of the structure will be preserved by side restraints in the form of flexible bracelets. The top of the structure will be surfaced by a number of cast iron cap plates, which will protect the channel entrances and will act as channel guides for the fuel charging and discharging equipment. The burst fuel element detection pipes will be also located by means of these plates.

Pressure Vessel.—The pressure vessel containing the reactor core will be a vertical cylinder supported on specially designed rocking feet to take up thermal movement. Adaptations of the techniques already established at Calder Hall will be used for the fabrication of this vertical cylinder.

Shielding Structure.—Shielding will be provided around the reactor main pressure vessel, gas ducting, blowers and pipework penetrating the biological shield, to attenuate the radiation to a safe level.

The main biological shield will be of reinforced concrete 8ft 6in thick. The top shield will be about 11ft thick, but because of control rod equipment voids, the effective thickness will be 8ft. The inner faces of the biological shield will be air-cooled by an induced fan system and protected from neutron bombardment by a steel thermal shield. The cooling air will be filtered before being discharged from the fans into atmosphere by two steel chimneys with a height of 240ft above ground level. The fuel element discharge chute will also be ventilated by this system. These chimneys and associated filters will deal with all gas and active or potentially active ventilating air in a manner compatible with the " Recommendations of the International Commission of Radiological Protection," as revised on December 1, 1954.

Fuel Charging and Discharging Equipment.—Replacement of fuel elements with the reactor on load will be the function of the fuel charge and discharge equipment which will be provided with heavy shielding to protect the operator. The design of the charge and discharge machines is such that no parts are left permanently in the reactor and no electrical equipment is introduced into the pressure vessel. Replacement of faulty fuel elements is possible at full reactor load.

Irradiated fuel will be carried in shielded coffins away from the reactor area and stored under water in special cooling ponds for the necessary decay period of 100 days, after which the fuel can be shipped to the chemical processing plant.

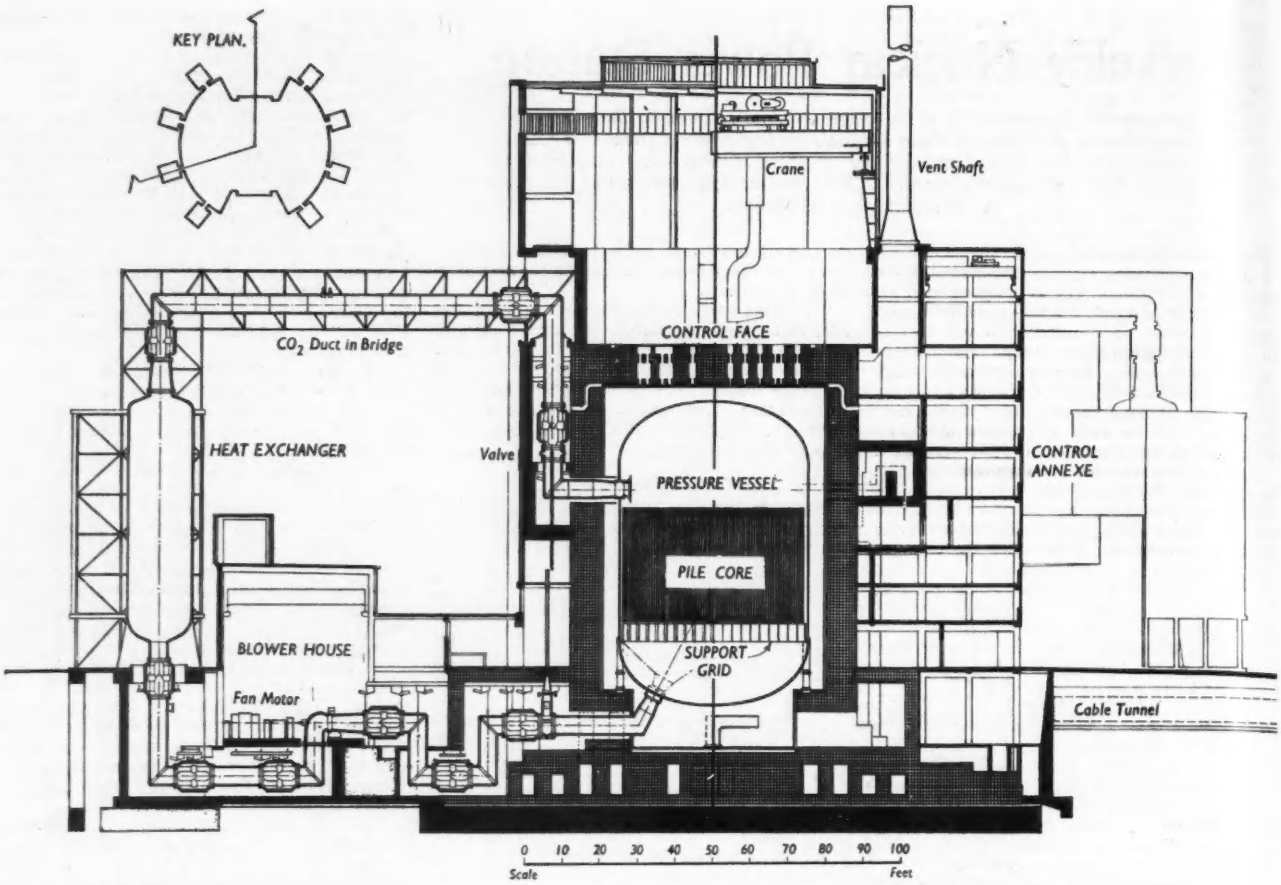
Burst Fuel Element Detection

The equipment for detecting burst fuel element cans will be similar in principle to that used at Calder Hall, but with detailed improvements. It is designed to detect and locate the failure of a fuel element can sufficiently early to allow removal of the defective element before any significant increase in activity in the coolant circuit can occur. This method of leak detection, which was described in our issue of October 19, 1956, page 538, depends on the fact that two of the most abundant fission products, krypton and xenon, are gaseous and that these decay to form solid subsidiary products which are themselves radioactive.

Samples of the coolant gas will be drawn through tubes from each of the fuel element channels in the reactor and passed, after cooling and mixing in groups of four channels, through a multi-selector valve to a filter which will remove solid particles, including any radioactive foreign matter. Then they will be passed to an electrostatic precipitation chamber and finally returned to the main coolant circuit by a compressor. In the precipitation chamber the solid subsidiary products, from the decay of the gaseous fission products, will be collected and passed into a chamber containing a scintillation counter to measure the beta activity of the deposit. The electrical output of the counter will be counted and recorded and will initiate the operation of a visual or audible alarm in the event of excessive channel activity.

Operation and Control

Operation of the station will be centralised in a control room from which each reactor, its blowers



Section through reactor of Berkeley nuclear power station. Each of the two reactors is graphite moderated and gas cooled, with eight heat exchangers

and its turbo-alternators, will be adjusted to maintain load at the desired level. Starting of individual plant items will be done locally upon telephone instructions from the control room engineer. Normal running having once been established, control will pass to the central control room. Operating control positions will be provided in the central control room, in the gas circulator houses in each reactor building, and on the turbine floor in the turbine hall.

The main functions of the reactor supervisory instrumentation provided in the central control room will be as follows :

(1) Continuous indication and recording of neutron flux.

(2) Continuous indication of : (*a*) selected fuel element temperatures ; (*b*) inlet and outlet coolant gas temperatures, and (*c*) position of each control rod.

(3) Preselected periodic logging print-out of fuel channel activity by automatic typewriter initiated by digital computer system with magnetic drum memory storage.

(4) Comprehensive visual audible alarm system giving ample warning of the onset of a non-urgent fault condition.

(5) Automatic reactor shut-down system initiated by urgent fault conditions.

Electric and pneumatic telemetering systems will relay the readings of reactor instruments to the central control room. Gas circulators, steam raising units and turbines, will be provided with standard flow, temperature and pressure measuring instruments, appropriate telemetering being employed where necessary.

Control of the station output will be effected by regulation of the reactor gas temperature. Individual items of plant and auxiliaries having been started up and the control centralised as mentioned above, the reactor control rods will be slowly withdrawn with the gas circulators running at a low speed. The plant temperatures will then be raised at a controlled rate, when steam production has reached an adequate level, the turbines will be started up by the turbine drivers. At the same time, the steam-raising unit steam pressures and control rod positions will be suitably adjusted by the central control room operator to maintain rates of rise of reactor temperatures at the desired level. The gas temperatures having reached normal, the gas circulator speeds will be increased as the turbines are loaded up.

The turbines will be frequency-controlled, the load being changed by speeder gear adjustment. Reactor gas outlet temperatures will be maintained constant at all loads by automatic control of control rod position. Thus, plant load changing will be by blower speed and turbine speeder gear control only. Automatic control of the latter from h.p. steam pressure would permit single-switch load control of the whole plant.

To shut down, the control rods will be run into the reactor in the normal way. Because of the cooling of the core and the decay of fission products, an output of heat will continue for a very limited period. In emergency the main gas circulators will be driven by d.c. auxiliary motors during the initial shut-down period, but after a short while the plant will be cooled adequately by the gas flow induced by natural convection.

Gas Storage and Ducting

Storage capacity will be provided on the site for sufficient gas to charge the reactor. The storage installation will consist of suitable tanks to contain liquid gas under pressure, together with evaporators and other auxiliary equipment, including the necessary pipework and valves to connect the storage tanks to the main gas ducts and various auxiliaries.

The main gas ducts will be of mild steel, designed, manufactured and tested in accordance with B.S. 1500 severe duty where applicable. Flanged joints will be reduced to a minimum, site circumferential welding being preferred because of the elimination of leakage risk. Access to all parts of the gas ducting after erection will be possible through manholes. To limit the continued accumulation of entrained particles in the gas circuit, cyclones and ceramic filters will be by-passed across the main gas circulators. Drying equipment will also be incorporated to maintain the moisture content of the gas within acceptable limits. Blow-down pipework and filters will be included to permit any section of the gas system to be discharged to atmosphere through the chimneys. Exhausting equipment will enable the air to be evacuated from the gas circuit before charging.

Gas Circulators

Gas circulation will be effected at 125 lb per square inch by single-stage axial-flow fans driven by a.c. squirrel cage induction motors (each of more than 3000 h.p.) through scoop-controlled fluid couplings. Variation in the gas quantity handled by the circulator will be obtained by altering the speed. The speed will be determined by the slip in the fluid coupling, which will be capable of variation by an electro-mechanical actuator altering the position of the scoop. A small d.c. motor will be incorporated to drive the circulator at a low speed and to provide a flow of cooling gas through the reactor in the event of a.c. failure. It will be designed to start automatically under these conditions.

The lubricating system will be divided into two parts, comprising that for the fluid coupling and gear couplings and that for the seal and bearings. A self-contained distilled water system in each circulator house will be used to cool the circulator lubricating oil and other reactor auxiliaries. The distilled water will in turn be cooled by the main circulating water.

Each of the sixteen steam-raising units will be enclosed in a cylindrical steel pressure shell about 70ft high by 17ft 6in in diameter. Steam will be generated in two separate circuits at two pressures—306 lb and 62 lb per square inch gauge. At both pressures the steam will be superheated to 612 deg. Fah. The steam-raising units will be equipped with forced circulation pumps to provide increased velocity of water and steam mixture in the evaporator sections and thus enable high heat transfer rates to be obtained. Totally enclosed glandless pumps will be used.

Turbo-Alternators

The turbo-generating plant of the station will be of established design, with two turbines

associated with each reactor. The governor gear is suitably designed to maintain as nearly as practicable the reactor coolant temperatures constant over a wide range of loads.

The steam turbine will be a horizontal close-coupled tandem-compound mixed-pressure impulse machine with triple exhausts designed for a back pressure of 0·43 lb per square inch. Deaeration of the feed water will be carried out in the condenser, in which the tube arrangement is such as to reduce the oxygen content of the feed water to a minimum. The feed heating system will consist of two stages of feed heating and includes ejector heaters and gland heaters. Fluctuations in feed demand will be met first by a supply of water from a pressure head tank and subsequently by supplies from the large reserve feed tanks.

Provision will be made for condensing steam which is discharged from the high pressure and low pressure receivers on any of the following occasions: (*a*) initial tests on the reactor; (*b*) starting up and shutting down of plant; (*c*) emergency shut-down of turbo-set or reactor; (*d*) shutting down of reactor.

Electrical Equipment

All the electrical auxiliaries will be supplied on the unit system, the unit consisting of one reactor and its associated steam-raising units, together with the two turbo-alternator sets which it supplies with steam.

The station will have two such units, each capable of operating independently of the other, but it will be possible to run No. 1 reactor with Nos. 3 to 4 turbo-alternator sets and vice versa. The station electrical distribution will have three main subdivisions.

A high-tension (6·6kV) a.c. system will supply all motors above 150 h.p. and the various auxiliary transformers. Nothing less severe than a busbar fault on this system could cause simultaneous shut-down of as many as four gas circulators. Only the extremely unlikely coincidence of a fault on the main transmission system and loss of both turbo-alternator sets, could cause loss of all eight gas circulators.

A low-tension (415V) a.c. system will supply all motors of 150 h.p. and below. It will be fed from the 6·6kV unit and station switchboards by means of stepdown transformers. It also will be designed to minimise disturbance through the reactor gas circulators under electrical fault conditions. The auxiliaries associated with each turbine will be supplied from the corresponding unit switchboard. Thus, in the event of one turbine being shut down, the corresponding turbine auxiliary board could be shut down without interference with the other sets. Auxiliaries which will be common to all turbo-alternator sets and which will be required during shut-down periods, will be supplied from two turbine-house boards fed from transformers from 6·6kV station boards. The turbine-house boards will also supply lighting, heating and power services.

A 240V d.c. system will supply all essential auxiliaries and will be used for stand-by and control circuit service. The system is in three independent sections (No. 1 reactor-house section; No. 2 reactor-house section; and turbine-house section), each supplied by its own battery and quite isolated from the others.

The turbine-house section will be conventional. The reactor-house sections will supply many other reactor auxiliaries in addition to the shut-down cooling for the reactor. Consequently, the power requirements are very large and continuity of supplies so essential that no protection is included on the leads to the battery. To eliminate busbar faults, however, the positive and negative busbars will be physically segregated.

Circulating Water System

The circulating water plant will follow conventional practice, the details of design being dictated by the siting of the station.

The circulating water will be taken from and delivered to the River Severn and will pass through guard screens and intake tunnels to the pump-house. The intake tunnels will feed main c.w. pumps which will be interconnected to provide a flexible system. These pumps will discharge into separate culverts carrying the circulating water for each turbo-alternator. After passing through the condensers the circulating water will return to the river through the four outfall culverts, one serving each turbo-alternator. The system thus provides a straight-through flow in which, under all normal operating conditions, the velocity in the tunnels and culverts will be such as to inhibit silting.

The cooling water system for the reactor auxiliaries will be connected in parallel with the condensers of the turbo-alternators. A d.c. auxiliary pump will be installed in the pump-house to provide emergency shut-down cooling for the reactor auxiliaries in the event of complete electrical failure in the station. Should, however, this d.c. auxiliary pump fail for any reason, the reactor will not suffer serious damage as the gas circulating system is designed to provide convection cooling.

The gas circulators for the two nuclear reactors will be supplied by the British Thomson-Houston Company, Ltd., who will also provide more than 900 auxiliary motors with outputs ranging from 750 h.p. down to fractional horsepower and totalling about 22,000 h.p. The associated control gear and transformers, rectifiers and diesel-driven stand-by sets, and the control-rod actuators (about 150 per reactor) will also be of B.T.H. manufacture.

The four turbo-alternator sets will be made by Metropolitan-Vickers Electrical Company, Ltd.

The 1000-ton reactor pressure vessels, steel thermal shielding, fuel-handling machines, gas cooling circuits, and the sixteen heat exchanger towers will be built by John Thompson, Ltd.

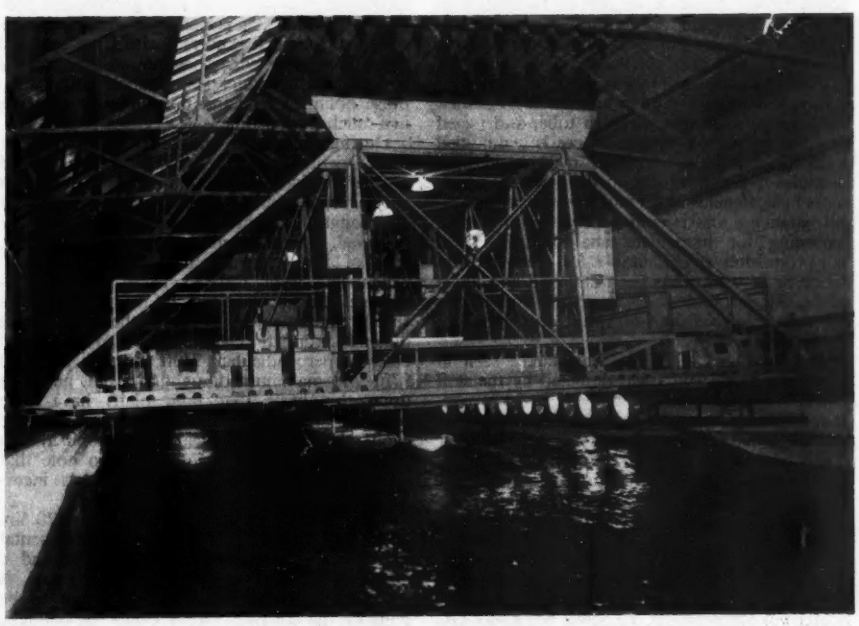
Responsibility for the civil engineering work will be shared by Balfour Beatty and Co., Ltd., who will do the turbine-house and its associated civil works, and John Laing and Son, Ltd., who will be concerned with the civil work on the reactor and heat exchangers.

Ship Model Experimental Tank

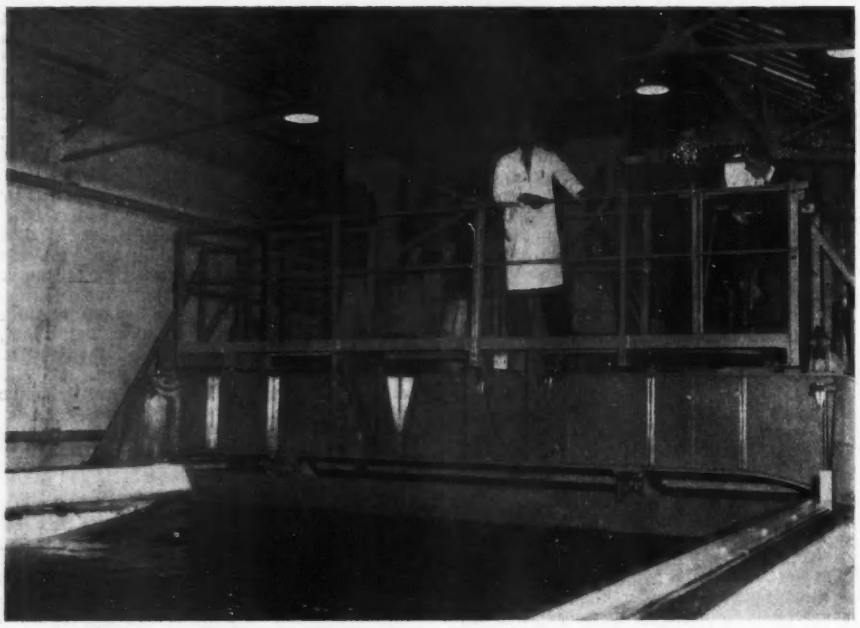
IT was William Froude who developed the theory that the power required to propel ships could be predicted from resistance measurements made on models by applying his law of comparison. The correctness of Froude's prediction was demonstrated by work carried out in the first experimental tank which was built at Torquay in 1872, and since then the value of carrying out model tests has influenced many shipbuilders and governments to construct ship model experimental tanks. The first to realise the usefulness of the experiment tank was William Denny, who, in 1884, built one at Dumbarton for his own company and to its considerable advantage. Although other firms were interested, it was not until the early years of this century that John Brown and Co., Ltd., constructed a tank at Clydebank, to expand its technical facilities. Some years later specifications were approved by Sir George Owens-Thurston, for a tank to be built for Vickers, Sons and Maxim, and it was erected at St. Albans in 1912, the first model being run in 1913.

The models used are normally made of paraffin wax and range in length from 10ft to 20ft, the weight being from ¼ ton to 1 ton. They can be towed or self-propelled in calm water or in wave systems and the various forces measured, while a record is taken of the motion of the model under the action of different wave patterns. From these measurements the equivalent figures are deduced for the full-scale ship and her performance predicted both as regards propulsion and sea kindliness. The correlation between model and ship is checked by records taken on the ship when on trial and on service. Most of the early work at the tank related to the design of naval vessels, but when this work diminished after the First World War, a certain amount of work on seaplanes and flying-boats was undertaken, work which eventually was taken over by the tank at the Royal Aircraft Establishment at Farnborough. However, with the company turning from warship building to the construction of passenger liners and oil tankers, the tank was used for the investigation of merchant ship forms and the compilation of data on a wide range of cargo ship models.

Following repair after bomb damage during the Second World War, the facilities were placed in the service of the Admiralty Experimental Works, Haslar. Since the war the greatly increased demand for model testing decided the company to reorganise the establishment at St. Albans and during the last ten years work has gone forward with the renewal of the whole of the equipment. This involved the provision of a new carriage which was designed and built at Barrow, and which can be seen towing a model of the Orient liner "Oriana" in our illustration. It is of all-welded tubular construction, weighs



View showing carriage towing model of "Oriana" in waves



Mechanical wavemaker showing bridge structure and the plunger

approximately 9 tons and is driven at speeds up to 20ft per second by four motors, each of 5/20 h.p., having Ward Leonard control. The principal instruments mounted on the carriage include a resistance dynamometer which measures model towing forces up to 50 lb with an accuracy of 1/100 lb. Autographic recording is arranged for ease of operation and also to assist in obtaining immediate analysis. A motion recorder, of modified Froude design, gives a continuous record of the heaving and pitching of the model under the influence of waves, while a sinkage recorder records the bodily vertical movement of the model in still water. These instruments have been designed and made by the staff at St. Albans, as have some of the "Dekatron" decade counters which give a mean reading over a specified time period to record carriage speed and propeller revolutions per minute. An electrically-operated stop-watch gives the time taken to travel a known distance and so acts as an alternative recorder of the speed of the carriage. Metropolitan-Vickers Electrical Company, Ltd., and the tank staff jointly designed and built the propeller speed control unit. It has electronic control of the output from the metadyne generator, giving constant torque at the propeller shaft and simulating the action of a diesel engine with correct racing and cut-off should the propeller emerge clear of the water.

For fitting in the models, there are stainless steel shafts running in water lubricated "Tufnol" bushes carried in a brass stern tube, and jigged to suit any size of model. There is a modified form of Admiralty designed mechanical self-propulsion gear for tests in calm water, which measures propeller thrust and torque by mechanical balancing and is equipped with autographic recording for immediate analysis. Electrical self-propulsion gear, suitable for tests in calm water or in waves, has been designed and made at St. Albans, and measures thrust and torque by electronic recording of strain on thrust and torque blocks.

Recently installed is the wavemaker, seen in our illustration, which was designed by the staff and constructed at the company's Elswick works. It consists of a strongly constructed bridge which resists the vibration set up by the wavemaker and carries the driving gear.

The wavemaker consists of a plunger of inverted triangular cross section, extending the width of the tank; the rear face which measures 5ft 4in in height is vertical and the front face is inclined forward at an angle of 35 deg. The plunger is moved up and down in the water with a simple harmonic motion by means of a Scotch yoke mechanism, the power being supplied by a 25 h.p. electric motor which drives through a magnetic clutch, 2½ to 1 reduction gearing and a differential gearbox. The stroke of the plunger is adjusted by hand and the wave height and length, which are controlled primarily by the amplitude and frequency of the motion, have a range up to 2ft and 40ft respectively. Control gear can be set to give either constant speed, despite heavy fluctuation of torque, or a repeatable sequence of varying frequencies, resulting in trains of regular or irregular waves. A bulkhead across the tank ensures that the waves travel in one direction and the waves break on an artificial beach so that reflections are prevented. At a point about mid-length of the tank is a wave height recorder which autographically records, with automatic continuous calibrations, the height of the wave as measured electronically by means of a fixed probe.

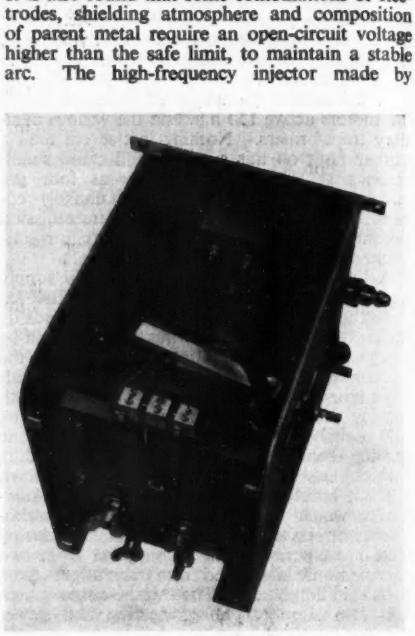
In addition to the model cutting machine and associated equipment, there is a propeller milling machine which was designed and built at St. Albans last year. Starting off with a clay model, a mould is eventually produced from which a rough casting of the propeller is made. Two cutters are used, one for the face and the other for the back of the blade, controlled from a tracing arm which follows the shape of a wooden model which is several times larger than the propeller required. The accuracy of the machine is such that the pitch is correct with ¼ per cent and the thickness is correct within a tolerance of 0·002in, both results being much better than those obtained by hand finishing and achieved in a much shorter time.

During our visit to the tank, the model of the Orient liner "Orsova," which sailed on her maiden voyage in 1954, was run at varying speeds and in waves of varying height and length, so that its behaviour could be observed. Another model was also on view, that of the new passenger liner "Oriana," which has been ordered from Vickers-Armstrongs, Ltd., by the Orient Line. To satisfy a speed requirement of 27 knots, the approximate dimensions of the ship require to be length between perpendiculars 740ft, breadth moulded 97ft, and maximum draught 31ft 6in, and it is upon this basis that lines plans have been prepared and models are being made in order to evolve the most economical form combined with sea kindliness. It was interesting to note that the model at present undergoing tests incorporated a bulbous bow.

The tank itself has an overall length of 447ft 6in, of which 376ft 6in is available for experimental purposes, with a breadth of 20ft 10in and a depth of 11ft 3in. At present the staff is engaged in testing hull forms of ships to be built by the company or by other shipbuilders, and on research work both for the company and for the British Shipbuilding Research Association. Work for the latter includes part of the methodical series investigations of ship resistance which is concerned with the effect on resistance, of ocean-going merchant ships, trawlers and tugs, of the variation in parameters such as the block coefficient, the position of the longitudinal centre of buoyancy, breadth/draught and displacement/length ratios. The effect of waves of different heights and lengths on performance is under examination; an investigation, using a self-propelled model of a cargo ship, into the phenomenon of slamming is intended to establish the exact wave conditions and pitching period at which slamming occurs and to measure the pressures on the ship's hull. A ship among waves is subjected to varying bending moments, in addition to those already set up by the distribution of weight and of buoyancy in still water, by reason of the constantly changing distribution of buoyancy supporting the hull: as part of the investigations into the measurement of the bending moments set up by waves, an articulated model fitted with strain gauges is undergoing tests among waves and the bending moments recorded.

High-Frequency Injector for Arc Welding

In welding processes using an electric arc it is sometimes desirable to start the arc without allowing the electrode to touch the workpiece. It is also found that some combinations of electrodes, shielding atmosphere and composition of parent metal require an open-circuit voltage higher than the safe limit, to maintain a stable arc. The high-frequency injector made by



High-frequency injector for arc welding. It is designed to start and maintain a stable arc without requiring the electrode to touch the work and without danger of shock. The covers are removed to show the components

Metropolitan-Vickers Electrical Company, Ltd., Trafford Park, Manchester, 17, is designed to provide a solution to both these problems by superimposing a high voltage on the output of the welding transformer or generator at a frequency sufficiently high to remove danger of electric shock. As illustrated here, the equipment, contained in a welded steel box, consists of a high-voltage transformer with a secondary voltage of 4000V, a capacitor, a double spark gap with tungsten points, and a water-cooled, air-cored transformer to inject the high-frequency voltage into the welding circuit while isolating the power-frequency high voltage from it. The secondary winding of the air-cored transformer carries the full welding current and is suitable for 400A continuous, or 450A on intermittent duty. The power consumption of the unit is 100W.

This unit can also be used in conjunction with a Metropolitan-Vickers flow control unit for inert-gas arc welding. For such work a relay is fitted so that a single push-button switch operates both units.

Testing Machines of Unit Construction

When it was decided by W. and T. Avery, Ltd., to introduce a new range of tensile and universal testing machines, a detailed investigation was carried out with a view to simplifying design and introduce unit construction. This article gives some particulars of the new machines and of the preliminary development work.

FOR many years, W. and T. Avery, Ltd., Soho Foundry, Birmingham, has specialised in the design and manufacture of testing equipment and this firm decided some time ago to introduce a new range of tensile and universal testing machines ranging in capacity from 500 lb to 100 tons. Before actual design was put in hand the firm carried out a detailed investigation to ascertain the deficiencies and advantages of its existing machines, and, so far as possible, the type and range of accessories needed or likely to be needed for the machines. At this stage of development it was decided to divide each of the various sizes and capacities of the proposed machines into basic units. Broadly, these units were classified as follows :—The straining or loading unit which applies the load to the test piece and carries the grips, holders and platens ; the load measuring and indicating unit ; the control unit, and the power supply unit. Various accessories, such as autographic recorders, load pacing equipments and automatic control equipments were designed for use with the basic units. The basic units were then standardised for production in reasonable batch quantities and to enable ready assembly with the other units in a variety of ways to cover a wide range of specifications.

It was originally hoped that one design of indicator equipment could be used for the whole range of capacities from 500 lb to 100 tons by coupling to suitable straining, power supply and control units. In practice, it was found, however, that the indicator unit for the larger capacity machines needed a more elaborate specification which made it uneconomical on the lighter capacity, simpler machines. Accordingly, two basic indicator units were evolved, both working on the same principle, but one being smaller and simpler, and consequently cheaper, than the other. The principle of simplification and standardisation evolved from the basic units was carried through to individual components. No component was designed for production until it had been ensured that there was no existing component which could be used in its place.

The makers quote an illustration of the application of the principles of simplification in the method of selection of machine capacities and chart ranges, which is of interest. Normally, machine capacities are chosen quite arbitrarily, and when detailed design is undertaken difficulties arise in the satisfactory design of charts to avoid having awkward non-decimal subdivisions on two chart ranges with a similar subdivision.

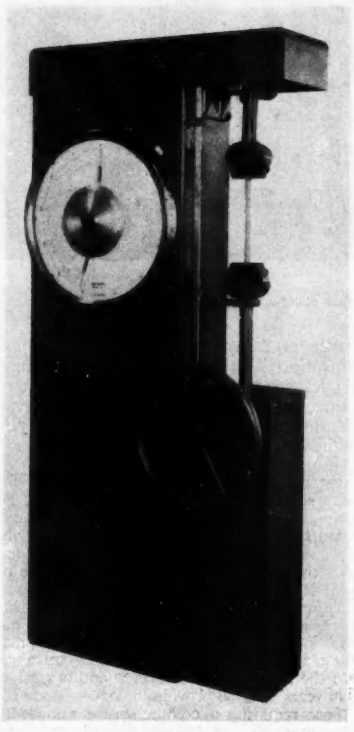


Fig. 1—Hand-operated, 12,000 lb capacity tensile testing machine of unit construction

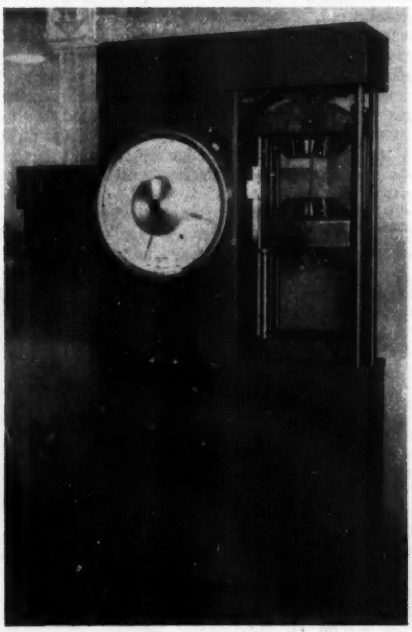


Fig. 2—Power-operated 12,000 lb capacity universal testing machine fitted with autographic recorder and pacing gear

For the new machines it was decided in respect of the smaller of the indicator units :—

(1) To standardise the maximum number of graduations on the chart at 300.

(2) To limit the variety of subdivisions to the ratios 1, 2 and 5.

(3) To arrange the machine capacities and chart ranges so that each change of capacity or range involved no change of subdivision.

(4) To arrange the machine capacities so that graduations in tons, pounds or kilograms could be provided.

As a result the following basic chart graduations were decided upon :—

Chart 1 (full capacity)	Chart 2 (half capacity)	Chart 3 (one-fifth capacity)
500× 2	250×1	100×0·5
1200× 5	600×2	240×1
2500×10	1250×5	500×2

These basic markings can be extended decimally and they are now used for machines having three or six load ranges and for units of pounds, tons or kilograms. By this means, it has been possible to provide seventeen different machine capacities involving sixty-three chart ranges from three basic master charts. The possible number is limited only by the range of machines manufactured.

The way in which the firm's policy of simplification has been carried out can be seen from the accompanying illustrations of the new machines. The main body structure of machines from 500 lb to 12,000 lb capacity is the same and Fig. 1 shows the simplest type of the new tensile testing machine with a capacity of 1200 lb by 5 lb divisions, consisting of a dial load measuring unit, transmission levers, and a hand-operated straining unit, using a screw with worm and wheel reduction gear. On the same kind of machine, the hand-operated straining unit can be replaced by a power-operated hydraulic unit. In it a piston-type ram and cylinder take the place of the screw and the gearbox, and the motor-driven pumps, oil tank and control valves are housed in the main cabinet for which provision is made in the detail design. In this way, changing the units used in an assembly rather than introducing a different series of components, has simplified production and extended the range application of the basic machine.

In Fig. 2 there is illustrated one of the new universal testing machines of 12,000 lb capacity, which has been built up on the unit system. This particular machine is equipped with an electrical autographic recorder and pacing gear, and shows the change from the simplest specification to an elaborate one which is necessary to meet individual requirements. For example, some machines may be required for a single purpose, such as routine control tests on the tensile strength of strip material or wire, whereas others, such as that illustrated, may be required to carry out research and design tests on widely differing materials ranging from plastics to cast iron or cement.

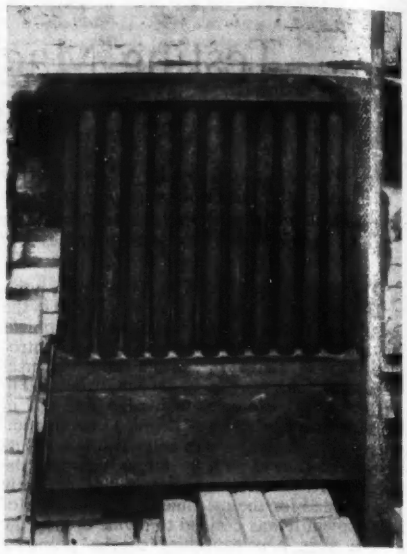
The standard 50-ton universal testing machine shown in Fig. 3 is based on the same principles. In this case the separate indicator unit is large and elaborate as in it provision is made for electronic controls for load holding and load cycling, and for a different method of changing the capacity range. For such machines of 10 tons capacity and upwards the four standard straining units provided are of 10, 25, 50 and 100 tons strength. These straining units are built separately from the load measuring and control equipment and individually adjusted, calibrated and tested. The standard power supply units used for the machines from 10 tons to 100 tons capacity each consist of a duplex three-piston pump running at a relatively slow

Fig. 3—50-ton universal testing machine of standard unit construction. Provision is made in its indicator for electronic controls for load cycling and holding

speed. The hollow pistons work inside cylinders to provide a high output of low-pressure oil for rapidly moving the working table and grip holders, and outside fixed plungers to provide the smaller supply of high pressure oil for straining. The control system on a hydraulic testing machine demands precise and automatic build-up of load, which means very small quantities of oil at high pressures for rigid materials during their elastic behaviour, and much larger quantities of oil during the plastic yield. A logarithmically scaled admission valve satisfies this requirement. Friction in transmission of the load from the test piece to the indicator unit is reduced to negligible proportions by the use of packingless rams which are continuously lubricated. The flow of oil for lubrication of the rams is provided by a compensation valve, avoiding loss of pressure.

Following the general principle of unit construction the sizes of rams and cylinders have also been standardised so that different capacities can be provided by changing the oil pressure. In an earlier type of machine made by the firm the oil pressure was standardised and this involved the use of a much larger range of cylinder and ram sizes than is now required.

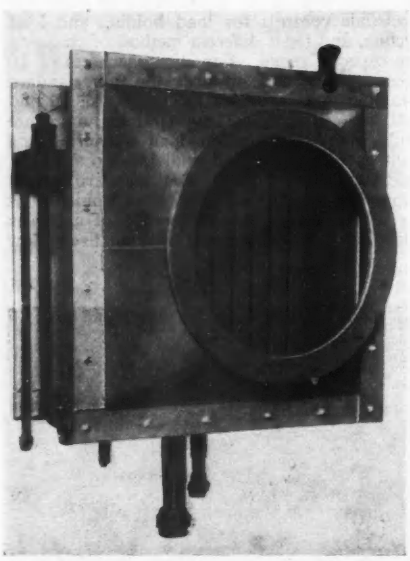
The electrical motor control gear of the machines is housed in an accessible panel which can be removed for assembly and servicing purposes. It was not possible for all the electrical units to be concentrated so the limit switches and other controls are located at the point of operation, whilst the connections were carefully arranged to provide for assembly and service.



Early design of d.c. pattern screen

Grit Arrester and Smoke Abatement Equipment

A RECENT development which has been designed to remove grit from flue gases and so prevent its emission to the atmosphere is the "Water Screen" spark and grit arrester, which is manufactured by Meldrum, Flood Page, Ltd., of Napier Yard, West Ferry Road, Millwall, London, E.14. The equipment, has been primarily designed for use with refuse destructors, and can be fitted to Lancashire, Cornish, Economic, waste heat, and other boilers in the flue between boiler and chimney, provided that a short length of flue can be expanded to take the water screen. In principle, the design is based upon the centrifugal action of high-velocity gases and the attraction existing between running water and minute particles in suspension.



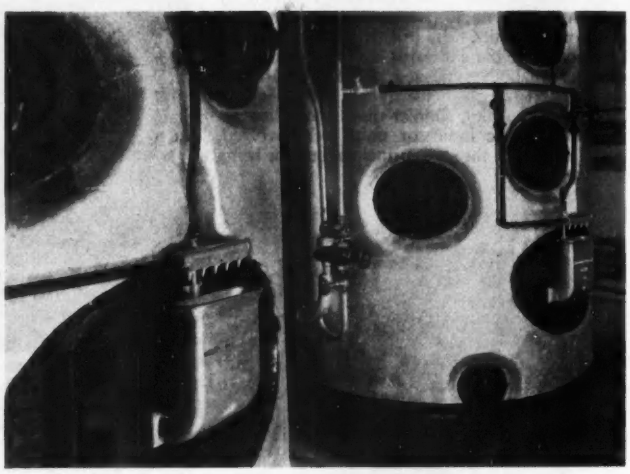
"Independent" pattern water screen with elliptical tubes

Briefly, the water screen consists of a header box of rectangular section and built of mild steel plates welded together, and rows of open-ended steel tubes welded, at their lower end, to the header box. There are mains water connections to the header, from which a length of piping is led to a tell-tale tube and drain box, mounted outside the flue and visible to the boiler operator. The header box is generally built of ¼in thick mild steel plate sides and base, with ⅜in thick top and end plates. Holes to take the tubes are flame cut in the top plate and then the solid drawn mild steel tubes are welded in position after setting by gauge. The tubes, which have walls generally about 10-gauge thick, have a bore ranging from 1in to 2½in, although the more usual size in use has a 1¼in bore. Before fitting, the tubes are rolled into an elliptical shape and slotted at the top. Early designs did not have slotted pipes, the slots being introduced to effect economies in the amount of water used, since the slots restrict the flow of water to that of the surface of the pipe facing the gas flow. Two or three banks of tubes are arranged depending upon direction and volume of flow and spaced so as to avoid any restriction of gas flow. The tell-tale tube is connected to the header box and fitted so that the top of the pipe is level with the lower edge of the slot in the water screen pipes, and in a position clearly visible to the operator.

Water is supplied to the header box from mains supply or elsewhere and rises up the water screen tubes to overflow through the slots and then flow downwards on the outer surface of the tubes and thence to drains. Instead of being allowed to run to waste the contaminated water can be recovered by fitting a settling tank, a storage tank and cooling arrangements. A valve regulates the flow of water, the adjustment being governed according to the flow visible at the tell-tale. The hot gases carrying fly ash and grit have to pass through this screen of running water, consisting of staggered rows of pipes forming a vertical maze, and in so doing precipitate matter to the film of water flowing down the tubes.

The photographs which we reproduce show an example of an "Independent" water screen in which can be seen the banks of elliptical tubes and the water flow tell-tale, and an early design of a "D.C." pattern screen. This embodies round tubes without slots, there being twenty-three of 2in bore. The unit was fitted in a destructor plant incorporating a waste heat boiler of 2500 lb per hour capacity and has been operating for fourteen months at a temperature approaching 1000 deg. Fah. Examination showed that there was only a light scale deposit in the tubes, which was easily brushed off. However, the manufacturers advise that the equipment is not suitable where sulphur dioxide or other corrosive gases are present.

Another piece of equipment which is a contribution to the problem of smoke abatement is the company's "controlled secondary air equipment." This system provides a simple supply of secondary air over a boiler grate and so helps to prevent smoke nuisance, to eliminate soot formation on heating surfaces, to improve combustion when inferior fuel is used, and to generate greater heat yield from the fire bed. Our illustration shows the equipment fitted to a pair of vertical boilers, and it can be seen that it consists of a casting, mounted on the firing door, which forms a venturi through which the secondary air enters the combustion chamber. Above the casting are arranged a number of steam jets and the necessary pipe connections. When fuel is being added, additional secondary air, necessary to complete combustion and prevent the formation of black smoke, is induced by opening the valve supplying steam to the jets. The air enters the combustion chamber in a stream, which breaks up any stratification of the flue gases, while another steam jet inside the chamber helps to increase the turbulence. The consumption of steam is small, since it is only required for a short period after firing.



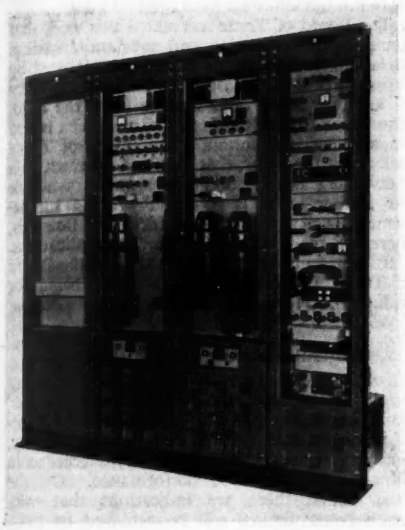
Controlled secondary air fitting

APPRENTICE TRAINING SCHEME.—An apprentice training scheme started by F. Perkins, Ltd., Peterborough, provides four forms of apprenticeship. The craft training scheme, designed primarily to produce skilled craftsmen in a variety of trades, extends over four years. The student scheme offers four kinds of career in engineering design, engineering production, laboratory and commercial work. A two-year post-graduate scheme is designed to enable engineering and art graduates to obtain practical training and experience before taking up a career within the Perkins organisation; and a special one or two years' scheme provides a concise study course for those requiring a comprehensive knowledge of Perkins products. A training school, set up at the firm's Eastfield factory, has a staff of five instructors and a senior instructor and provides training facilities for sixty apprentices.

Multi-Channel Radio-Telephone Link for Portugal

A COMPLETE u.h.f. frequency-modulated, wide-band radio telephone link between Lisbon and Montijo, in Portugal, is to be supplied by the Automatic Telephone and Electric Company, Ltd., Strowger House, Arundel Street, London, W.C.2. The radio equipment for this link will be provided and installed by Marconi's Wireless Telegraph Company, Ltd., Chelmsford, Essex, and will consist of two " HM 200 " multi-channel equipments and the associated aerials. An interesting innovation in this equipment will be the use of three new travelling-wave tubes for amplification of the ultra-high-frequencies.

This installation, which will establish a 14km radio telephone link spanning the River Tagus between Lisbon, in the north, and the rapidly growing industrial district of Montijo, in the south, will provide, initially, sixty (and ultimately 240) radio telephone channels. The Automatic Telephone and Electric Company's carrier equipment will be installed by the Anglo-Portuguese Telephone Company, at the two terminal points —Graca, an automatic exchange in the centre of Lisbon, and Montijo, where a new building will be erected to house the radio equipment and a tandem exchange. The equipment being employed will be basically the same as is used in coaxial systems.



Terminal equipment for u.h.f. frequency-modulated multi-channel radio-telephone link. A sixty-channel equipment of this kind is to be installed in Portugal to span the River Tagus and link Lisbon with Montijo

The Marconi " HM 200 " equipment, which is illustrated here, operates in the frequency band 1750 to 2300 Mc/s, which offers the advantages of broad modulation bandwidth and high aerial gain. The difficulties of multiple-frequency conversion at these ultra-high frequencies, and the power handling limitations of the mixers used, are avoided in the " HM 200 " equipment by the use of travelling-wave tubes. Briefly, the travelling-wave tube (examples are illustrated below) is a device which can provide direct amplification at u.h.f. and s.h.f., and which, because of its wide bandwidth and high gain, is considered superior to the klystron and the disc-seal triode for multi-channel radio links such as the one considered here.

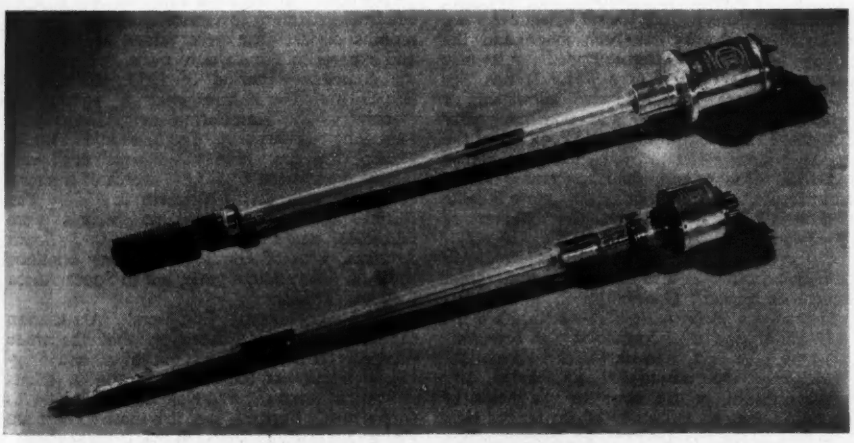
At the terminal the traffic signal from the channelling equipment is amplified in a conventional wide-band amplifier and is converted to a frequency-modulated signal at an i.f. of 70 Mc/s, in a special three-valve modulator circuit. This i.f. signal is taken to a crystal mixer stage, where it is mixed with a carrier frequency in the 2000 Mc/s band. The carrier frequency is obtained via multipliers from a crystal-controlled oscillator. The modulated u.h.f. signal is taken from the mixer stage through a band-pass filter and is applied to an intermediate travelling-wave tube. The intermediate tube drives a high-power tube which is used as a power amplifier to deliver 10W to 15W output to the aerial feeder.

The incoming signal from the receiving aerial is applied to a low-noise travelling-wave tube of special design, having a noise factor of better than 10 db. The amplified output from this tube is mixed with the output of a crystal-controlled local oscillator to give an i.f. of 70 Mc/s. After amplification the i.f. signal is demodulated to the base-band frequency and the traffic signal is applied to an output line amplifier.

To ensure consistent reliability, high-grade selenium rectifiers are used to convert the d.c. supplies required by the terminal equipment. Stabilising circuits are employed for the h.t. supplies to the modem equipment. Neon tubes and corona discharge tubes are used to stabilise some of the supplies to the travelling-wave tubes.

The equipment operates into spun aluminium paraboloid aerials of 10ft diameter, each having a nominal gain of 30 db over a half-wave dipole. The reflector is centrally illuminated by a waveguide horn of special design, and vertex plate compensation ensures optimum matching. The aerial is normally mounted in a frame which may be supported on a mast or tower. Waveguide feeders, pressurised with nitrogen, are used.

As illustrated here, the terminal equipment consists of four racks : one for the transmitter and associated power supply components ; one for the receiver and its power supply components ; one for the modulator, demodulator, and supervisory panels (the " modem " rack), and one filter rack.



Travelling-wave tubes for the multi-channel radio-telephone equipment linking Lisbon and Montijo. Because of their wide bandwidth and high gain these tubes will be used, instead of the klystron and disc sealed triode, for u.h.f. amplification

Lloyd's Register of Shipping

THE shipbuilding returns for the quarter ended December 31, 1956, have been published by Lloyd's Register of Shipping and state that in Great Britain and Northern Ireland 328 steamships and motorships of 2,135,218 tons gross were under construction, being an increase of 57,242 tons over the previous quarter. During the quarter seventy-two ships of 429,781 tons were commenced, while those launched amounted to eighty ships of 492,445 tons, and the total completed was seventy-six ships of 377,290 tons. This latter figure added to that of the previous three quarters brings the total of ships completed during 1956 to 1,457,000 tons gross, compared with the 1,538,000 tons completed by Japan during the year. A total of sixty-three oil tankers of 908,189 tons was under construction, a figure which is 65,625 tons more than the previous quarter and represents 42·5 per cent of the total tonnage building. Of the tonnage being built in this country, 447,394 tons, or 21 per cent, is for registration abroad, as compared with 40·4 per cent in September, 1950. Abroad the work in hand consisted of 1247 ships of 5,929,850 tons gross, an increase of 558,816 tons since the September returns, and included ships building in Poland for the first time since March, 1950. Progress during the quarter amounted to 445 ships of 1,755,829 tons commenced, 433 ships of 1,573,000 tons launched, and 421 ships of 1,376,276 tons completed. Oil tankers under construction amounted to 186 ships of 2,535,210 tons, which is 384,573 tons more than at the end of September and represents 42·8 per cent of the total building. Tonnage for registration in a country other than where building increased by 216,281 tons to 2,860,144 tons and amounted to 48·2 per cent of the total under construction. The world total, including Poland, of work in hand amounted to 1575 ships of 8,065,068 tons gross, of which 26·5 per cent were under construction in Great Britain and Northern Ireland. A total of 249 oil tankers of 3,443,399 tons, or 42·7 per cent of the total tonnage, was under construction. The steamships and motor ships being built included 145 ships of between 6000 to 8000 tons, 155 ships of between 8000 to 10,000 tons, 126 ships of between 10,000 to 15,000 tons, thirty-two ships of between 15,000 to 20,000 tons, sixty-nine ships of between 20,000 to 25,000 tons, twenty steamships of between 25,000 to 30,000 tons, six steamships of between 30,000 to 36,000 tons, and two ships of 50,000 tons each. Ships building under the inspection of Lloyd's Register totalled 4,610,258 tons, or 57·2 per cent of the world total.

British Standards Institution

All British Standard Specifications can be obtained from the Sales Department of the Institution at 2, Park Street, London, W.1.

ASBESTOS CEMENT PRESSURE PIPES

No. 486 : 1956. Price 4s. This specification indicates that increased availability of asbestos, and improvements in the qualities provided, have made it possible to specify a reduced wall thickness for asbestos pressure pipes—whilst still retaining a high factor of safety. Some simplification has also been effected by standardising in the smaller diameters a single thickness for more than one class of pipe, e.g. in the 2in diameter pipe the thickness is the same for all four classes and for the 3in diameter it is the same for classes A and B, and for C and D.

In this revised standard, there are additional tests for water absorption, bending, crushing and solubility in acid. The collars or other connecting devices have been dealt with in greater detail than previously, and requirements for any form of rubber joint ring are given. Requirements are also given for a suitable coating solution for both pipes and jointing collars.

An appendix gives a series of precautions which should be observed when attaching ferrules to asbestos cement pipes in order to avoid undue weakening of the pipe.

Industrial and Labour Notes

Britain's Overseas Trade

At the beginning of the week, the Board of Trade issued its review of the United Kingdom's overseas trade in 1956. It shows that the total value of exports was £3172 million, which was rather more than 9 per cent above the 1955 figure. In volume, the Board of Trade says, last year's exports were about 6 per cent higher than those of 1955. When certain unusual factors about both years are taken into account, there was evidently a "small acceleration in the underlying rate of growth of exports in volume in 1956, and a rather more marked acceleration in the growth in value." Export prices over the whole of last year were almost 4 per cent higher than in 1955.

But, the Board of Trade comments, the expansion of United Kingdom exports must be seen against a background of continued rapid growth in world trade as a whole. In the first three quarters of 1956, world trade in manufactures was 15 per cent higher in value and 11 per cent greater in volume than in the comparable period of 1955. The acceleration in the growth of United Kingdom exports, therefore, has so far been "sufficient only to diminish the rate at which our share of the growing world market is declining, but not to halt the decline."

As in the two preceding years, the largest part of the rise in the United Kingdom's exports in 1956 occurred in the engineering field. Last year, the emphasis was on exports of ships and aircraft, though there was also a further substantial gain in the group comprising industrial plant and machinery. Last year's exports of road vehicles were much the same as those of 1955, an increase for commercial vehicles and chassis being offset by a fall in exports of passenger cars. Exports of engineering consumer goods on the whole showed little change last year, although, the Board of Trade comments, these were the commodities most directly affected by the credit squeeze at home.

Productivity

Among the annual statements by Bank chairmen which have been circulated during the last few days are those by Sir Eric Carpenter, of Williams Deacon's Bank, Ltd., and Lord Aldenham, of Westminster Bank, Ltd. In a review of economic affairs, both of them comment on matters related to industrial productivity.

Sir Eric Carpenter says that productivity was disappointing in 1956, and that when the final assessment can be made it will probably show little or no increase on the year. In so far as this follows from reduced production of consumer goods with a high import content, it is a desirable thing for the time being and is, Sir Eric suggests, "what the restrictions were meant to achieve." Fortunately, his statement continues, the credit squeeze does not seem to have had any disastrous effect on industrial investment during 1956, and, though there are differences between the various industries, plans for 1957 are similar in total amount. Such slowing down as there has been is in the rate of increase in investment, and it follows, therefore, that British industry is in a good state to take advantage of an upsurge in activity. The risk is that it might be held back if restrictions were kept on for too long, for there is no point in creating increased productive resources and then not using them fully. In the meantime, Sir Eric says, it should be borne in mind that our principal rivals, the United States and Germany, have both had further rises in productivity during the year. Wage increases negotiated in the first half of 1956 added 6½ per cent to wage rates. In the same period retail prices rose by 2 per cent and productivity hardly at all, so that there was some addition to the inflationary pressure. It was at this point that the Chancellor made his appeal for a halt to increases in wages and prices, and many firms agreed to fix their prices for a period ahead. Although the T.U.C. would not agree to wage restraint and applications have set in for further increases, they have so far been settled at a more modest figure, and in the interests of the community as a whole, Sir Eric adds, it is to be hoped that this course will continue. Everyone, his statement says, wants a rising standard of living for the whole population, but it can only be attained by acting with a sense of responsibility, by using our resources of brains, labour and materials in the best possible way, and avoiding all waste and inefficiency whether due to disputes, faulty methods or out-of-date machinery.

In the Westminster Bank statement, Lord Aldenham refers to the great progress made "in bettering our factories and plant during 1955 and 1956." He says that an important and far-seeing step has been taken by many leading industrialists in setting up a fund to assist in the training of more technicians for the management of those improved factories. But, Lord Aldenham continues, in spite of the improvement of our fixed assets, the larger number in civil employment than ever before, and the fewer man-hours lost in labour disputes, the production of manufactured goods did not increase in 1956. Part of the explanation, it is suggested, is to be found in the fact that the overall figures for employment conceal a good deal of short-time working, particularly in the motor industry, though this, Lord Aldenham comments, is not the whole story. Government policy, he says, has aimed at securing a redeployment of manpower, reducing the numbers engaged in the manufacture of consumer goods and diverting them to the production of capital goods and to the export industries. During 1956, this process was going on, and the lag in production, Lord Aldenham asserts, is part of the price that is having to be paid to secure a redistribution of manpower.

Planning Problems

The problems of planning are commented upon in the annual statement which Lord Harlech has prepared as chairman of the Midland Bank, Ltd. He says that in the shaping and carrying through of plans by public authorities and private businesses there is to be found the crucial element in the determination of the ups and downs of economic activity. It seems often to be assumed, the statement continues, that "planning" is the simple answer to the problem of economic instability, whereas in practice the timing and balancing of plans, in such a way as to ward off or allow for economic fluctuations, is a most delicate and difficult operation. This is true for both government and business, even though government, besides full authority over its own plans, has extensive powers to influence those of other public bodies and of private business. These powers, Lord Harlech adds, the government of our own country has repeatedly called into use in recent years, with not altogether happy results.

Lord Harlech goes on to say that a prerequisite of successful economic policy is full knowledge of the facts, obtained in time to prompt any corrective action that may be found necessary. In this respect, the statement observes, remarkable progress has been made and the government is now better equipped for its new responsibilities than it ever was. It has, for example, more comprehensive estimates of consumers' expenditure and various other elements in the composition and disposal of the national income; improved measurements of industrial production; data concerning actual and prospective capital outlay, and more reliable and detailed figures about the balance of payments.

But even when adequate statistics are forthcoming, Lord Harlech suggests that great difficulties remain. One weakness, he says, lies in a tendency to presume that statistics are the only valid kind of information for economic planning. In fact, non-statistical information, particularly the day-to-day knowledge and impressions of people close to the fields of operation, may sometimes be of greater practical help than the bare statistics in detecting a turning point in the course of affairs. A government authority concerned in such matters, Lord Harlech considers, should take steps to ensure constant sensitiveness to the "feel" of things, especially as to the development of business plans concerning capital expenditure and stocks, the prospective course of prices, sales, orders on hand, and so on.

Loan Facilities for Small Manufacturers

About three years ago, as part of the Conditional Aid programme, a £700,000 "revolving loan fund for industry" was established for the purpose of assisting the increase of productive efficiency. Loans from the fund have been made to engineering, plastics, printing and textile firms. They are short-term loans to enable suitable small manufacturers to purchase up-to-date equipment and adopt modern techniques. The fund does not, however, provide assistance for building work. In order to spread the benefits as widely as possible, loans of more than £30,000 are not normally given, though no fixed maximum or minimum amounts have been laid down.

The Board of Trade has stated this week that increases in production and substantial savings in labour and materials have been reported by firms which have been able to improve efficiency as a direct result of assistance from the fund. The major part of the fund has now been issued or is under negotiation. The Board of Trade points out, however, that the fund operates on a "revolving basis," and the amount available for further loans is continually being supplemented as repayments are made. The Board is, therefore, ready to consider further applications. Further details may be obtained from the Board of Trade, I.M.2 Division (Revolving Fund for Industry), Horse Guards Avenue, London, S.W.1.

Agricultural Machinery Industry's Prospects

In a report on this country's agricultural machinery industry, the Agricultural Engineers' Association says that last year ended in a "flurry of increased activity." It does not seem likely, however, that in 1956 the industry succeeded in improving on its 1955 performance. On the other hand, there are indications that very much better figures will be achieved in 1957, particularly in relation to production and exports. For both tractors and agricultural machinery, production continued to increase in the last two months of last year. The rise in tractor output was the greater, and in November was well over the monthly average for 1955. There was a marked increase in sales to the home market during November, and in the same month both tractor and agricultural machinery exports were appreciably higher than in November, 1955.

The Association comments on various changes which occurred last year in Britain's markets for agricultural machinery. In Eire, sales of British equipment in the first ten months were 33 per cent smaller than in the comparable period of 1955, and exports to Italy fell by as much as 50 per cent. At the same time, exports of agricultural machinery to Germany in the first ten months of last year were valued at £434,685, and exports to France were twice as great as in the comparable period of 1955. Comparing British and German exports of agricultural machinery, the Association says Germany is increasing its lead in Belgium and France. During the first nine months of last year, Germany exported £4,373,847 worth of tractors, compared with £907,691 worth in 1955. The British figures for the same periods were £2,265,338 and £939,939 respectively. In South America, sales of German machinery continue to be on a substantial scale, but in South Africa they are diminishing.

The Agricultural Engineers' Association expresses confidence, however, that the trade prospects for British exports in 1957 are encouraging, especially as the economic and payments position of Australia and New Zealand continues to improve. Furthermore, it is stated, there are interesting trade prospects in the South Americas as their agricultural programmes continue to develop. But, it is added, "more sales effort will be required to maintain our present markets."

Portuguese Railway Electrification

A PRELIMINARY study, prepared some years ago, showed that it was feasible to electrify the suburban lines of Lisbon and Oporto as well as the Lisbon to Oporto line, using 3000V direct current. However, for various reasons, this programme could not be carried out and it was only in 1953 that it became possible to resume the studies started earlier.

Meanwhile, however, researches undertaken by the French Railways in co-operation with the leading European manufacturing firms had led to a new tractive system using current at 25kV, 50 cycles per second alternating current. This system, it will be recalled, allows the railway to use the general power network and thus secures considerable savings in the stationary equipment, the cost of the traction material remaining of the same order of magnitude. In the Portuguese case there was another favourable circumstance, namely the fact that the main power transmission lines of the Companhia Nacional de Electricidade were located near the railways, running along a direction roughly parallel to them.

It remained only to determine if the single-phase load of the railway substations did not unduly unbalance the three-phase network. New studies, undertaken in co-operation with Companhia Nacional de Electricidade, showed that the use of 25kV, 50 periods alternating current was quite possible.

Additional expenditure was caused by the 25kV system in the following respects : all telegraph and telephone lines parallel to or very near the railways to be electrified must be put into cable or alternatively their layout must be altered. The former solution is technically preferable, as it gives increased operational safety and considerably reduces maintenance costs ; it was therefore adopted by the Portuguese railways authorities for their own telecommunications.

It may also be found that the track in the tunnels and under bridge structures has to be lowered in order to obtain safe distances between the catenary and the ground. In Portugal it was found that the volume of these works did not affect to a great extent the economy of the system. The most considerable item was in connection with Rossio's tunnel, 2600m in length, where an average reduction of 50cm to 60cm was needed in the level of the track, as well as the construction of a reinforced concrete cill about 700m long.

The present programme of electrification concerns the suburban lines of Lisbon and Oporto as well as the northern line between Lisbon and Oporto. The first stage of this programme was completed last October, when the official opening took place of the Sintra Railway and the Northern line up to Entroncamento, involving 142km double track and about 6km single track. The second stage, Entroncamento–Oporto–Ermezinde, comprises about 218km double track and 24km single track. There are other lines, however, where electrification is being considered.

Work for the first stage was carried out by an international consortium comprising Swiss, German and French firms belonging to the electrical engineering, rolling stock and locomotive sectors, and one Portuguese railway carriage and wagon builder. The order included fifteen locomotives and twenty-five three-carriage railcar trains, as well as the construction of all stationary equipment, such as overhead lines, substations, remote control and signalling equipment.

Rolling Stock.—The engines (Fig. 1) are total adhesion locomotives of the type B_0-B_0. Each weighs about 70 tons (axle loading 17 tons), and has a continuous rating of 2500 h.p. at 65km per hour, and one-hour rating of 2700 h.p. at 63km per hour. Two driving cabs are fitted.

As a universal locomotive was desired, which could haul either fast trains at 120km per hour, or heavy freight trains at low speeds, a mono-direct tractive system was chosen, with the current rectified by an "ignitron" rectifier. This locomotive is designed to haul a 400-ton passenger train at 120km per hour on a level track ; to haul the same train at 91km per hour on a 1·4 per cent grade track ; on the same track to haul a 500-ton freight train at 68km per hour ; and to haul a 800-ton freight train at 53km per hour on a 0·9 per cent grade track.

The three-unit railcar trains for the Lisbon suburban services are built of stainless steel, according to the Budd patent. Each comprises one total adhesion motor coach with four motors having a total continuous rating of 1360 h.p. at 63km per hour, and a one-hour rating of 1500 h.p. at the same velocity, one intermediate coach and one pilot coach equipped with a second control cab. The trains are therefore reversible. It is also possible to couple up two or three three-unit sets to obtain six or nine-coach trains with one control. The maximum speed is 90km per hour.

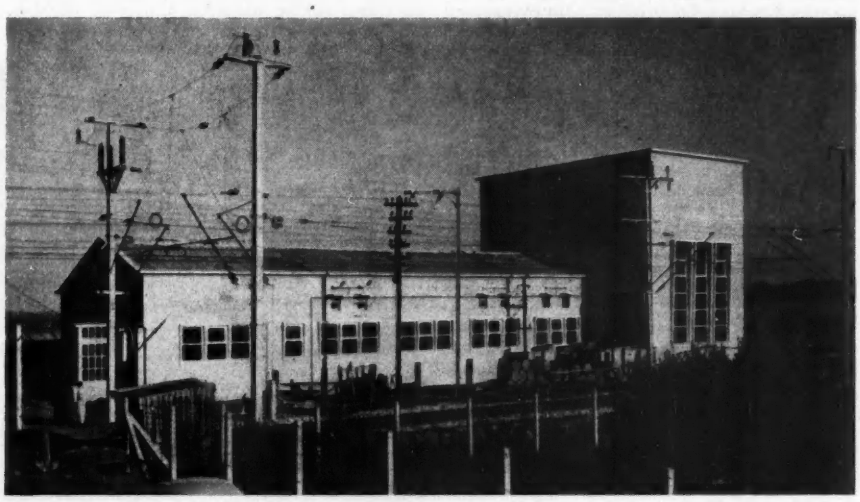


Fig. 2—Santa Iria substation

The new stock is equipped with central automatic couplings of the Scharffenberg design, compressed air braking and rheostatic braking in the motor coach, fluorescent lighting and emergency lighting, porous rubber padded benches in the first and second classes, sliding doors which shut automatically, and electric heating. In the interiors wood and paints were replaced as far as possible by light-coloured plastic meterials that are easy to wash. Each coach has two wide doors for the passengers. The three-unit railcar seats eighty-nine passengers in the first class and 211 in the second class, and, including standing passengers, can transport 500 people.

The following running times are anticipated, deducting the delay in the stops : Lisbon–Rossio to Sintra or return with twelve intermediate stops, in about twenty-nine minutes ; Lisbon–Rossio to Vila Franca de Xira or return with seventeen intermediate stops, in thirty-nine minutes. These running times represent a considerable improvement relatively to the old schedules.

Substations.—In the complete electrification five substations are planned at distances of 80km to 100km ; two of them, located at Santa Iria and Entroncamento, belong to the already completed first stage.

Santa Iria 10MVA substation (Fig. 2) receives current from the substation of the Companhia Nacional de Electricidade at 30kV three-phase. The three-phase current is transformed into two-phase current at 25kV by means of Scott connected 10MVA transformers. This is the only indoor substation. The other substations are for a primary voltage of 60kV and are outdoor installations.

The Entroncamento substation is to be fed from the Castelo do Bode power station by two three-phase, 60kV lines. The three-phase current

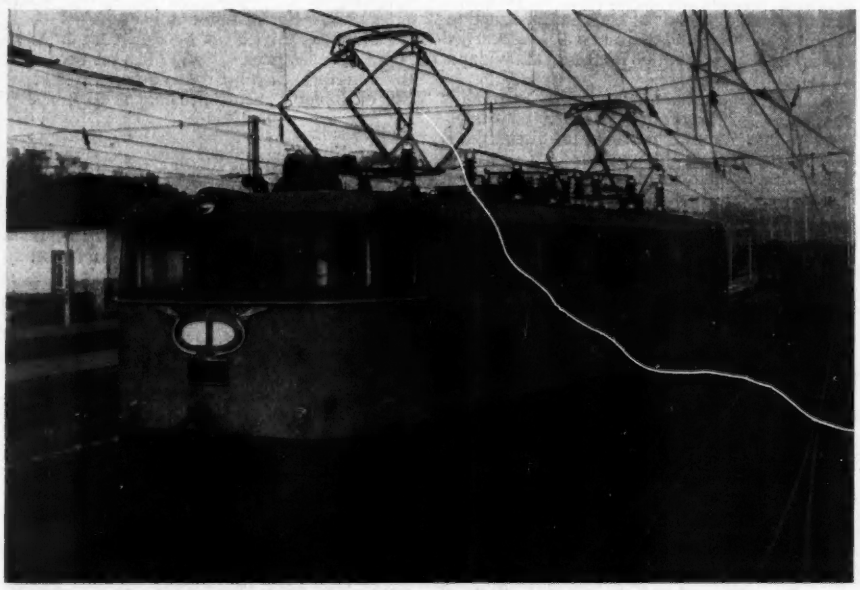


Fig. 1—70-ton, 2500 h.p., B_0-B_0 locomotive in service on Portuguese railways

is transformed into two-phase, 25kV by means of Scott connected 10MVA transformers.

Telecontrol and telemeasurement from the end substations will be included in the completed scheme.

Overhead Equipment.—This includes the overhead lines, poles and feeders. A light catenary of polygonal design was chosen, made up of one bronze cable with a 65 square millimetre cross-section from which the copper contact wire with 107 square millimetres cross-section hangs by means of suspensions placed 9m apart.

The height of the contact wire above the rail-head is 5·75m in the open, but can be decreased to 4·82m in tunnels and under bridges.

Stresses in the carrying wire and in the contact wire are controlled by means of counterweight devices placed along the track, about 1200m apart, in order to obtain constant tensions of about 1000 kg. For reasons of safety and easier maintenance the two catenaries on double track sections are separately supported. In the stations, where unobstructed visibility over several lines is essential, flexible supporting frames were selected, which can span up to 40m.

Between Santa Iria substation and Campolide station two feeders supply current directly to the Sintra line, a solution that increases operational reliability.

Signalling.—A good signalling system is essential to derive the maximum benefit from electrification without loss of safety. Thus the Portuguese Railways purchased automatic block equipment, by means of which trains can be dispatched with intervals of three minutes.

The new installations comprise automatic block control on the line Lisbon–Rossio–Sintra–Entroncamento; adaptation of the present block stations of Rossio and Campolide; construction of new block stations at Amadora, Queluz, Cacém, Sintra, Santa Apolónia, Braço de Prata, Sacavém, Vila Franca, and Entroncamento; the locking of block signals with the hand-operated switches in the stations and the turnouts between the stations, by means of "Bouré" locks, and warning signals on level crossings.

In the section Campolide–Sintra–Vila Franca de Xira track circuits are fed by 1000 c/s electric current supplied by electronic valves; between Lisbon–Rossio and Campolide by 125 c/s alternating current; between Vila Franca and Entroncamento by direct current.

At five of the major stations there are central block stations with all-electric interlocking systems.

At the remaining stations the switches are hand operated and are locked by means of "Bouré" type locks. The interlocking of the switches with the signals is obtained through electromechanical central locks, which make it possible to release the locking arrangement of the switches near the latter.

Optical and acoustic warning signals indicate the approach of trains in the level crossings, which are also equipped with international highway signals automatically controlled by the trains.

Telecommunications.—Between Lisbon–Santa-Apolónia and Entroncamento two cables are foreseen, one for long-range telecommunication and the other for short-range telecommunication, remote control and measurement; one cable only is used between Lisbon–Rossio and Sintra.

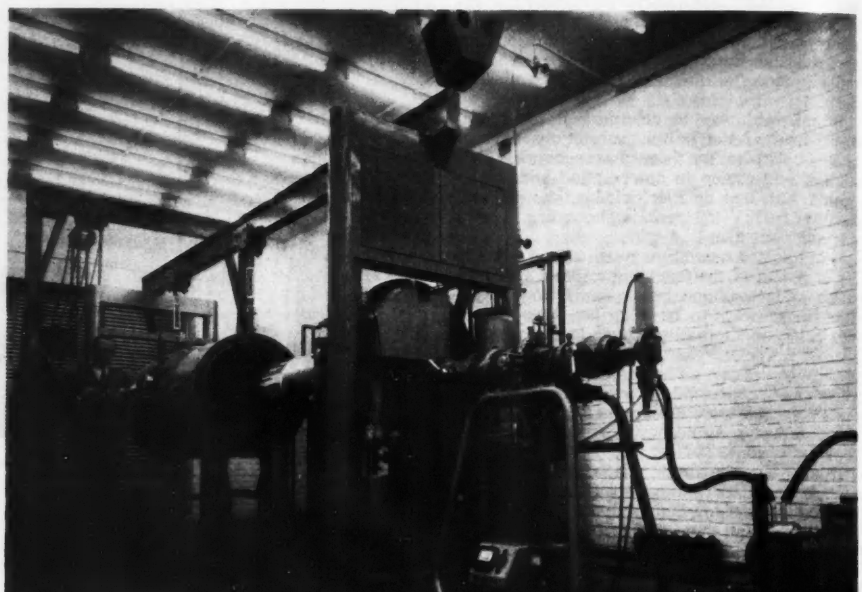
The opportunity was taken to modernise the present installations in order to improve the service efficiency. The centralised ringing selector telephones are replaced by a new installation by means of which calls for the secondary posts of the stations can be obtained in the central posts by simply pressing a button. Similar installations will be provided for the West line; the telephones replaced will be used on lines with a lesser density of traffic.

Automatic central exchanges connecting the Lisbon central services with the regional services will also be built. Telephone sockets are mounted along the track at intervals of 1km, in order to assure safety during maintenance and repairs of the track and overhead lines.

Another important aspect in connection with the telephones is the linking of telecommunication devices with the system of mechanical signalling and "Bouré" locks, allowing a station to be shut down for some time when such a step is justified by its reduced service and thin traffic. Thus a station can be put into the so-called "eclipse" régime, but the two stations operating up and down the line on either side remain connected. Telephones were also mounted in more than two-thirds of the existing level crossings for protection of railway and highway traffic and it is hoped to complete soon the equipment of the remaining third.

Van de Graaff Accelerator for Liège University

In the accompanying illustration we show the Van de Graaff particle accelerator of the Liège centre of the Belgian Inter-University Institute of Nuclear Science. The equipment has been produced partly by High Voltage Engineering Corporation, of Cambridge, Massachusetts, and by Ateliers de Constructions Electriques de Charleroi, Belgium. Capable of producing a tension of up to 2,000,000V, the machine will be used for a number of high-precision nuclear measurements, in particular that of the energy levels of nuclei. Construction, assembly, testing and adjustment were carried out under the direction of Professor M. Winand, of Liège.



2,000,000V Van de Graaff accelerator. The pressure chamber, which keeps the machine under 25 atmosphere inert gas pressure, is open, showing the dome electrode and insulating support which houses the accelerator tube. On the right are the pumps

At Liège, the column supporting the dome is constructed of forty-four metal discs with intermediate insulators. The danger of discharges is lessened by placing the machine in a container filled with a mixture of nitrogen and carbon dioxide under a pressure of 25 atmospheres. The container has a diameter of 92cm and a length of 200cm.

Particles to be accelerated are introduced from an appropriate source into a tube extending between the dome and the base of the machine. The acceleration which a particle undergoes by passing through the electric field is very large, speeds of the order of 20,000 km/sec being reached over a path barely 2m in length. Emerging from the tube, the particles hit a target in which they either produce nuclear reactions or an emission of X-rays or gamma rays. Since very low pressures of the order of 10^{-6}mm Hg or better have to be maintained in the accelerating tube against the stream of gas from the ion source, it is necessary to employ powerful pumping equipment.

Among the various uses of the Van de Graaff accelerator are radio biological and metallurgical researches, the study of the physical effects of radiation, radiotherapy, production of radio-active isotopes, radiography of metals up to 15cm thickness, and sterilisation of drugs and foodstuffs. In the nuclear field itself this kind of machine serves as a particle injector for giant accelerators like the Brookhaven cosmotron or the Bevatron at Saclay. The main application, however, is to precision measurements, where a very stable beam of particles of great homogeneity has to be used. While the initial beam, which has a strength of 50μA, shows variations in particle energies of 4–5 per cent, a stabilised beam above this variation is reduced to less than 0·1 per cent may be obtained by utilising the principle of feed-back. The beam is passed through a magnetic analyser, which produces a curved path, the curvature depending on speed. The beam emerges through a slit and, according to which side of the slit is hit by particles, that side gives rise to an electric current which after amplification regulates the accelerating voltage. The strength of the analysed beam is 25μA. In the Liège machine a radio-frequency ion source is employed, which, operating at 125 megacycles per second, emits either protons or deuterons.

Pumping is carried out by a mercury diffusion pump with a capacity of 500 litres per second at 10^{-4}mm Hg, backedby a rotary pump with a capacity of 10 cubic metres per hour at 10^{-2}mm Hg.

Productivity and Local Co-operation

With the help of the German Productivity Council (RKW), a number of leading personalities of Trier have started a movement "citizens help citizens." The sponsors who come from industry, local government and various associations, intend to conduct this movement—the first of its kind in West Germany—for a definite period, with the objective of increasing productivity. The principal aim is to remove causes of friction in the region's economic life by kindling a sense of communal responsibility among people at all levels. It is a frequently observed tendency among the public to regard shortcomings and failures occurring within the individual's sphere of work or environment, as being the responsibility of "the other fellow," which one could not, need not, or even should not, do anything about. "Citizens help citizens" aims at educating people to the opposite point of view and to establish machinery for dealing with the criticisms and suggestions which are expected to result.

High-Head Turbine Test Stand

BY OUR AMERICAN EDITOR

SINCE the advent of very large hydro-electric turbines some thirty years ago, the manufacturers of hydraulic turbines have experienced little difficulty in designing and building units capable of attaining 93 to 94 per cent efficiency. The major field of exploration in the laboratory, therefore, has been the development of runners with improved cavitation characteristics. Cavitation begins when the absolute pressure at any point on the runner vanes drops below the vapour pressure of the water, resulting in the formation of numerous bubbles filled with water vapour. These bubbles are carried quickly to areas of higher pressure when they collapse suddenly, producing shock pressure concentrations of great intensity, which eventually destroy the metal surface and cause pitting.

The Thoma cavitation index, σ, is commonly used to define the cavitation characteristics of a turbine. Sigma may be defined as the ratio of the barometric head (H_b) minus the static suction head (H_s) at any point to the total operation head (H) on the turbine :

$$\sigma = \frac{H_b - H_s}{H}.$$

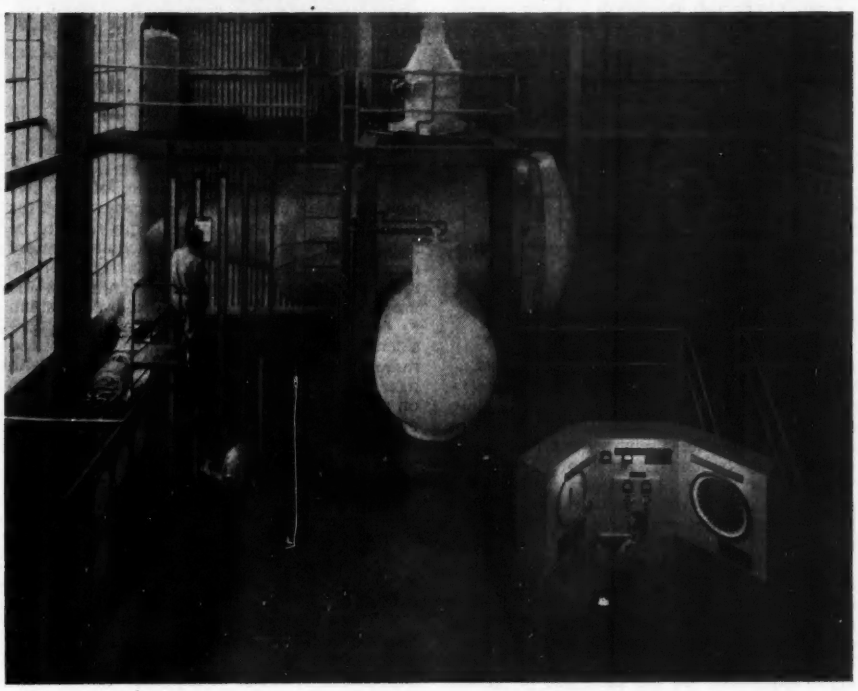
To determine the minimum allowable or critical value of σ in the laboratory, the model is usually tested with a constant wicket gate opening, and a constant blade angle in the case of a Kaplan turbine, at a constant speed under a constant head, while the elevations of headwater and tailwater are lowered step by step for successive runs until a definite break or change in performance is observed. In practice, a reasonable margin of safety above this break determines the operating limit for the corresponding head and load on the prototype. When the plant σ drops below the critical σ for any head and load, pitting, vibration and loss of output will result. In most cavitation laboratories considerable difficulty has been experienced in obtaining definite cavitation break-off points by plotting either efficiency, power or discharge against σ values. Consequently, in many laboratories the chief means of studying cavitation inception has been by visual methods utilising stroboscopes and other aids.

Recognising these early laboratory difficulties and limitations as well as the necessity of obtaining reliable numerical results in order to develop runners successfully to meet the modern requirements of higher speeds, smaller diameters and reasonable settings for any given head, the S. Morgan Smith Company, of York, Pennsylvania, recently installed a new high-head turbine test stand. From the outset it was decided that the primary function of this facility was to obtain accurate and reliable quantitative results, and provisions for visual testing received only minor consideration, since this work can be conducted in the low-head test stand existing at the same works.

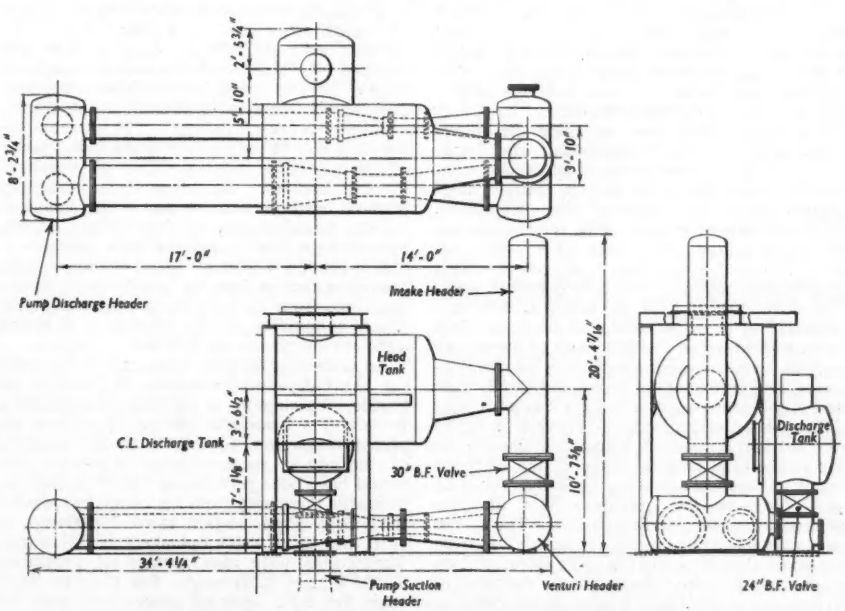
As shown in the accompanying illustrations, the pumps discharge water into a discharge header and then through either of the Venturi meters to the Venturi header. It was originally felt that the intake header would require 5ft of air cushion to smooth out operation, but it has been found unnecessary ; therefore the header is used as a collector, from which the air is allowed to escape when starting the test stand. The water flows from the intake header to the head tank and then through the turbine to the discharge tank. An air cushion is provided on the top of the discharge tank, and by adding compressed air, water under pressure or by evacuating air by means of a vacuum pump, the discharge pressure may be altered, thereby changing the value of σ during the tests. Numerous valves are provided for varying the test head on the unit. It is interesting to note that the head tank is large enough to accommodate a wheel case, a scroll and some penstock, if necessary. The repeatable accuracy of this stand is considered to be plus or minus one-quarter of 1 per cent ; the absolute accuracy is within 1 per cent.

One 300 h.p., 0 to 6000 r.p.m., eddy current dynamometer is used to measure the turbine horsepower. The load is applied at a 21in radius to a calibrated Emery cell and reads directly in pounds of load on the gauge board. The load cell calibration is checked periodically with a Morehouse proving ring previously calibrated by the National Bureau of Standards. The speed in r.p.m. is measured by a mechanical tachometer, driven from the shaft, and an electronic speed counter using a magnetic pick-up on the main shaft. The dynamometer also measures the down thrust on an Emery cell by hanging all the rotating components on the cell. The two Venturi meters provided are a 30in by 16½in unit and a 20in by 10in unit, which were calibrated at the Worcester Polytechnic Institute and the University of Pennsylvania, respectively. The meter selected for measuring the flow is determined by the magnitude of the manometer deflections. Roto valves are provided for shut-off service at the throats so that either Venturi meter may be used. Several manometers are available for reading the meter deflections.

Each of the two pumps circulating the water is rated at 9500 gallons per minute under 118ft head with a guaranteed efficiency of 86·5 per cent. Each 300 h.p. pump motor runs at 885 r.p.m. These pumps are arranged to operate in series or in parallel so that under a head of 300ft 5000 gallons per minute can be obtained from two pumps in series, and under a head of 100ft 21,000 gallons per minute can be obtained from two pumps in parallel. The graph reproduced



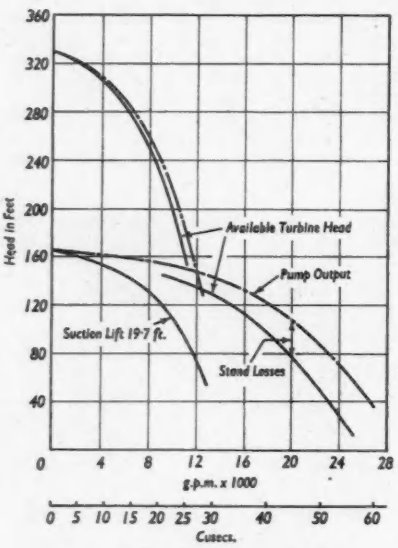
High-head hydraulic turbine test stand installed at the York works of the S. Morgan Smith Company in Pennsylvania



General arrangement of high-head hydraulic turbine test stand

herewith shows the head discharge conditions available for testing in the stand. Differential mercury manometers are used to measure the net head across the turbine below 150ft. Heise gauges are used to measure the inlet head pressure when the 150ft differential is exceeded. A mercury "U" tube manometer is used for measuring the discharge tank pressure.

A 7ft diameter head tank is provided, in which the wheel case is mounted. The elbow draught



Head discharge conditions available for tests on high-head stand

tube discharges through the bottom of this tank into the 5ft diameter discharge tank. A 100-ton water cooling system is used to maintain the 10,000-gallon stand capacity at a constant temperature. The water to be cooled is taken from the high-pressure side of the pump and returned to the suction side.

A few details of design and operation are noteworthy. At first, a stand capable of developing an 80ft head for 12in discharge diameter models was deemed satisfactory and rather extensive layouts were made for this design. However, upon studying the possibility of building a 300ft stand for the same size of models, this scheme was adopted for the following reasons: (1) the added expense of building a 300ft stand was not excessive; (2) lower σ values can be obtained more easily with the higher head, thereby allowing cavitation tests to be conducted conveniently even on Francis runners in the low specific speed range; and (3) field conditions of head and σ can be duplicated for all Kaplan and propeller designs and for many Francis designs, allowing more thorough investigations of actual operating conditions.

The entire wheel case, including the wicket gates and operating mechanism, stay ring, bottom ring and head cover, is suspended from the dynamometer frame and is entirely independent of the head tank and other components of the pressurised system. This is accomplished by attaching the wheel case to a cylindrical barrel, situated in the head tank, but separated from it by means of music note rubber seals. The advantage of this mounting is that any breathing or other movement of the pressurised tanks will not affect the alignment of the runner and shaft which is also attached to the dynamometer, and consequently excessive bearing wear and accompanying extra friction loss and other difficulties are eliminated. To remove the wheel case the barrel assembly is removed through the top of the head tank by means of the overhead crane. The wheel case assembly is then removed and placed on the laboratory floor for convenient dismantling and reassembly. The runner can be detached from the shaft and removed from the stand after lowering the short elbow portion of the draught tube. To determine the value of hydraulic thrust for each individual test point all rotating parts, including the turbine runner shaft and dynamometer rotor, are supported, by a Kingsbury thrust bearing in the top of the dynamometer stator, which in turn is suspended from an Emery load cell by means of a torsion-free rod. The torsion-free rod not only permits a convenient determination of hydraulic thrust, but also permits all of the torque developed by the turbine to be transferred to another Emery load cell equipped with an extremely accurate three-range indicator.

After the complete model is assembled in the head tank and the access door is closed and sealed the entire system is filled with water. The pumps are then started and the system is pressurised. All mercury and water manometers are bled and set at zero. Test runs are made at five-minute intervals, allowing one minute to set the new test conditions, three minutes for the transients to smooth out and one minute for the actual test. These runs can conveniently be made at three-minute intervals by decreasing the time allowed for the transients to settle, but the five-minute cycle allows each test point to be calculated and plotted as the test progresses. A complete test on a Francis turbine, including determinations of power and efficiency, cavitation, and run-away speed versus σ can be run in four days. Five men are used to conduct a cavitation test and are placed at the following stations: dynamometer control panel, Venturi manometer, head water manometer, tailwater manometer, and the computer's desk. Four of the five men used for testing double as assemblers for setting up and dismantling the equipment to be tested, which allows them to acquire a more detailed knowledge of the characteristics of the turbine tested. During the design stages the use of measuring equipment to allow the stand to be operated by one or two men was considered, but it was felt that greater accuracy and more consistent results could be obtained with men taking a number of simultaneous readings on all gauges during a run. Also, direct manometer reading is readily understood and allows cross-checking by the hydraulic laboratory technicians, the company's hydraulic engineers and visiting customers' engineers during acceptance tests, whereas electronic or other complicated conversion equipment would require the continuous services of instrument technicians. After completion of a test the stand can be shut down, drained and the runner removed in less than an hour.

The new high-head test stand is used for basic research and the conduct of formal contract acceptance tests with particular emphasis on the duplication of field conditions. The results obtained so far have been gratifying. The original hydraulic and mechanical design appears to have been quite sound and only insignificant modifications have been required since the stand was first placed in operation.

At present continuous basic research is being conducted in this stand on Kaplan and propeller turbines, with particular emphasis on high-head applications. This equipment has been extremely helpful for this work, as no trouble has been experienced whatever in accurately determining cavitation break-off points. Considerable research is also being planned in the investigation of the cavitation characteristics of high-head Francis turbines. Relatively little laboratory research has been done by any of the American turbine manufacturers on these wheels, mainly because high heads have not been available to obtain the low σ values. Most of the available cavitation data on these low specific speed designs has come from an analysis of field experience, which, although extremely valuable, is no longer sufficient for modern applications.

An account of the tests conducted on this stand for the Gorge power station of the City of Seattle, Washington, is particularly interesting. In fact, if a laboratory testing rig such as the present one were not available, the risk involved by the city in accomplishing its present aims would have been prohibitive. In 1921 the City of Seattle purchased from the company units for the Gorge power station rated 27,500 h.p. at 275ft net head when operating at 257 r.p.m. These units were also capable of generating 37,500 h.p. at 325ft head. For the past thirty years they have operated under 275ft head, but provisions were originally made for a future increase in the dam height to bring the net head up to 325ft.

In 1955, because of the great power demands in the Pacific Northwest, it was decided to make the alteration to the dam for the increased head and also to attempt to obtain 45,000 h.p. at 325ft head instead of the original 37,500 h.p. This increase of 20 per cent in capacity was desired at good efficiency (not less than 87·5 per cent) and with only minor alterations to the runner and wicket gate dimensions. Merely to achieve the increase in power would not have been difficult, but to do it efficiently and without serious cavitation, utilising the same value of plant σ, was a difficult task. When the company was approached with this proposition the following model test programme to be conducted in the high-head test stand was suggested to the city: (1) build and test a homologous model of the existing prototype unit, including runner, wheel case, spiral case, Johnson inlet valve and several diameters of penstock upstream; (2) design, build and test a half-step runner capable of producing 42,500 h.p. at full gate; and (3) design, build and test a full-step runner to generate 47,500 h.p. at full gate or 45,000 h.p. at 87·5 per cent efficiency.

The above procedure was accepted by the city and the programme is at present nearing completion. It was originally estimated that a $\frac{1}{2}$ per cent loss in efficiency could be expected in going from step (1) to step (2) and a $1\frac{1}{2}$ per cent loss from step (1) to step (3). However, test results have indicated that each of these steps can be made with only half of the anticipated efficiency losses. Test results have indicated also that the newly designed runner for step (3) has a critical σ value which is suitable for the original plant σ.

X-Ray Studies of Stresses in Metals

RECENT work at the National Bureau of Standards, Washington, D.C., has provided interesting information on the distribution of stresses between crystals in a metal. Studies of changes in the lattice spacing of crystals, both under load and after release from load, were made by X-ray diffraction. It was found that the magnitude and direction of the principal stresses can be computed for a certain loading condition in this way even though the elastic limit has been exceeded. The investigations have also led to a new explanation of the balancing of residual strains. These results, it is hoped, should not only increase the practical utility of stress measurement by X-ray diffraction, but should also prove useful in basic studies of metal fatigue and corrosion.

When a stress is applied to the crystal aggregate of a metal the behaviour of individual crystals depends on the orientation of the axes of the crystal relative to the direction of the stress. If the crystals are randomly oriented, the individual effects are averaged out and the metal behaves in a nearly homogeneous manner. However, the distribution of stress is not uniform from one crystal to the next, and it is important to measure these microscopic stresses in order to understand better such phenomena as fatigue and stress corrosion, which are restricted in their early stages to a single crystal or to the boundary between crystals. Since the presence of a stress causes a change in the interplanar spacing, X-ray diffraction provides a strain gauge for the crystal lattice. It is highly selective as only those crystals are measured that have a certain orientation relative to the X-ray beam, but by making the measurements with a number of different directions of incidence of the beam it is possible to study the strains in a high percentage of the crystals. Only elastic strains are measured, as plastic strain occurs without further change in the interplanar spacing.

Previous work at the Bureau and elsewhere has shown that there is a certain range of applied stress over which the crystal lattice behaves elastically; beyond this point the strain as measured by X-rays remains nearly constant although the metal continues to deform. Furthermore, when the load is released a residual strain is left, opposite in sign to that under load. The present investigation sought to answer such questions as the following: (1) is the elastic limit the same in all directions relative to the applied stress; (2) what is the nature of the

residual strain observed after plastic deformation and how is the stress causing this strain balanced ? To provide the necessary data an investigation of lattice strain in seventeen directions in a low-alloy steel was conducted by the Bureau's mechanical metallurgy laboratory. Measurements were made both under load and after release of load, the successive loads being of increasing magnitude. The specimen is shown in Fig. 1 and was a hollow cylinder $\frac{7}{8}$in in outside diameter, 2in long and $\frac{1}{4}$in in wall thickness, with portions machined away so as to leave a reduced section consisting of three symmetrically spaced legs $\frac{1}{4}$in long and triangular in cross-section. This design was adopted so that the specimen would be stable in compression and would not require large loads to obtain high stresses. The ends of the specimen were welded to supports carrying a central loading rod. A nut

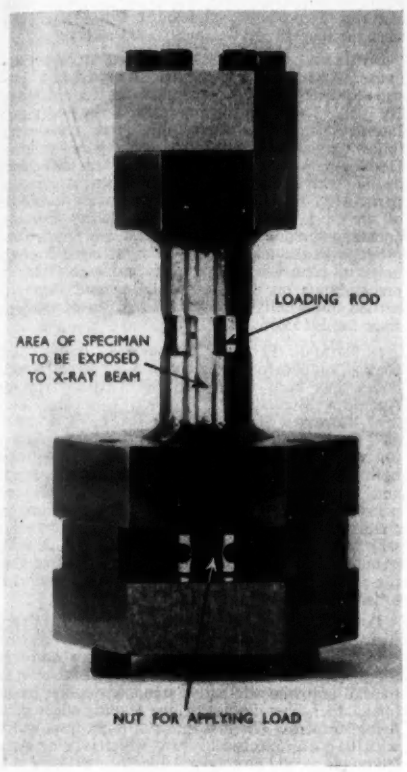


Fig. 1—Test specimen and tensile and compressive loading fixture

was threaded on to the loading rod so that a clockwise turn applied a compressive load and a counter-clockwise turn applied a tensile load. Because the nut and the far end of the loading rod made contact with the specimen supports through spherical surfaces, the load was distributed equally and axially on the three legs. The load was measured by wire strain gauges attached to the calibrated loading rod.

As shown in Fig. 2, the specimen and loading system were mounted on a two-circle goniometer so that the X-ray beam could be made incident at any desired angle relative to the specimen surface and the stress direction. Special precautions were taken so that the surface on which the strain measurements were made should have the same structure as the interior and would be initially free from strain. The diffraction patterns were recorded photographically and measured with a photoelectric micrometer developed for this purpose. To improve the inherently poor precision of the strain determinations three patterns were exposed for each loading condition, and the strain values were computed from the average of measurements on all three. Since a change in lattice spacing causes a change in the diffraction angle, the results of the experiment were summarised in diagrams showing the change in $-\tan 2\theta$ with load. As illustrated in Fig. 3, at low stresses the graph of $-\tan 2\theta$ versus load is a straight line, the slope of which is termed that

Fig. 2—Arrangement of specimen and loading fixture on two-cycle goniometer

lattice compliance. Deviations from this compliance line (i.e. the elastic limit) occur at lower stress for the positive compliance (stress and strain acting in the same sense) than the negative. This was found to be generally true in all directions investigated. The average stress values at which the deviations occurred were 23,000 lb per square inch and 40,000 lb per square inch for positive and negative compliances, respectively.

A study of the variation of lattice compliance with direction indicated that shear and transverse stresses were superimposed on the loading stress. Analysis showed that if such stresses were assumed to be proportional to the loading stress then the experimental values of compliance could be adequately represented by an equation derived from the elastic theory for a homogeneous medium. This implies that the ellipsoid of elastic strain is the same in all crystals measured, from which, if true, it can be deduced that there are steep stress gradients in the vicinity of the crystal boundaries. As previously mentioned, the residual strains on release of load beyond the elastic limit are opposite in sign to those under load, and, moreover, they increase with increasing load. It was found that the values obtained for the difference in tan 2θ, expressed as strain, which occurred on release of load for stresses greater than the elastic limit, could be predicted from the lattice compliance computed from the above-mentioned equation. This indicates that the magnitude and directions of the principal stresses can be computed for a certain loading condition from the change in lattice spacing on release of load even though the elastic limit has been exceeded.

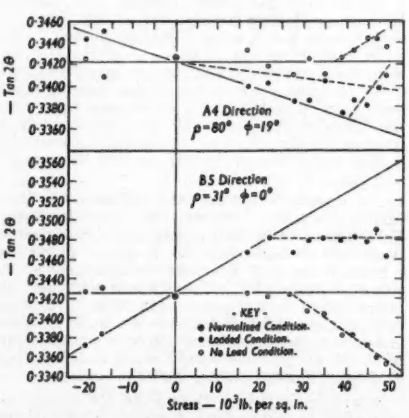


Fig. 3—Graph of $-\tan 2\theta$ versus load applied to test specimen

Other investigators had previously noted the development after plastic deformation of residual stresses opposite in sign to the applied stress, and various explanations have been offered to account for the necessary balancing stress. One theory is that the stresses are due to the anistropic behaviour of individual crystals and are balanced by opposite stresses in adjacent crystals of different orientation. The Bureau's results do not support this theory, as a wide range of orientations were studied and all of the residual strains appeared to arise from a single stress system. It has also been suggested that the observed stress occurs only in the surface layers of the plastically deformed specimen, the balancing stress being present in the interior. A study conducted by C. J. Newton and H. C. Vacher of the N.B.S. staff, indicates that this theory does not hold. Two specimens of ingot iron were plastically deformed, one in compression and the other in tension. Sections were cut from the bars at angles of 0 deg., 30 deg., and 90 deg. to the axis along which the stress had been applied, and X-ray strain measurements were made on the surfaces of these sections. Assuming that the cutting of the specimen relieved the stresses normal to the new surface and that the stresses parallel to this surface were not affected by the sectioning, it was possible to reconstruct the residual stress system existing in the bars before they were cut. These stresses were similar to those previously found on the outside of specimens, namely, a compressive stress in the tensile specimen and vice versa. As the experimental results do not agree with any of the current theories, the N.B.S. investigators propose the following explanation for the balancing of the observed residual strains : it is suggested that this balancing is supplied by stresses in material in which the crystal lattice is so distorted that it does not scatter X-rays coherently and that such material might be found at grain boundaries or in slip bands. The spring and ratchet model shown in Fig. 4 illustrates a

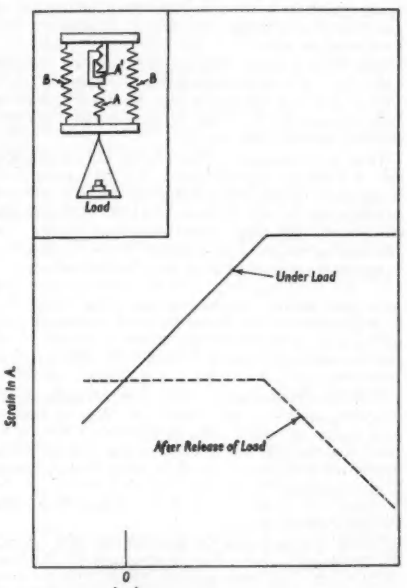


Fig. 4—Spring and ratchet model illustrating the development of residual strains in metals after plastic deformation

suggested explanation for the development of residual strains in metals after plastic deformation. The spring A and ratchet A' represent the elastic and plastic properties of the crystal lattice, while the springs B represent the elastic properties of material that does not contribute to the diffraction pattern. A load placed on this system could be measured by the strain in A until the stress was sufficient to operate the ratchet. A removal of the load would then place A in compression and B would remain in tension. The curves for the load and no-load conditions are qualitatively similar to those obtained experimentally for those directions in which there was an elongation under tensile load.

Personal and Business

Appointments

MR. JOHN KAY has been appointed west of England representative of Martonair, Ltd.

THE DOWTY GROUP, Ltd., states that Sir Godfrey Ince has been appointed a director.

MR. J. MCAFEE has been appointed assistant chief engineer surveyor of Lloyd's Register of Shipping.

ASSOCIATED ELECTRICAL INDUSTRIES, Ltd., has announced that Lord Bicester has been appointed a director.

MR. L. BAILEY has been appointed works manager of the United Steel Structural Company, Ltd., Scunthorpe.

MR. E. L. HALLE, M.I.Mech.E., has taken up an appointment as a consulting engineer with Peregrine and Partners.

MR. K. ROWELL, A.M.I.C.E., A.M.I.Mech.E., has been appointed a director of W. H. Allen Sons and Co., Ltd.

MR. H. G. BOWLES has been appointed assistant general manager (administration), Western Region, British Railways.

EASTERN REGION, BRITISH RAILWAYS, announces the appointment of Mr. R. E. Evans, A.M.I.C.E., as district engineer, Ipswich.

MR. J. F. DRYSDALE has been appointed product sales manager of the Rex-Rotary section of the supply division of Remington Rand, Ltd.

MR. J. WORMALL, M.I.E.E., has been appointed industrial sales manager and local director of Laurence, Scott and Electromotors, Ltd.

MR. JOHN STUART BRIGHT, A.M.I.Mech.E., has been appointed general manager of F. Perkins (Canada), Ltd., Toronto, in succession to Mr. D. H. Milnes.

THE MINISTRY OF TRANSPORT AND CIVIL AVIATION has announced the appointment as a part time member of the British Transport Commission, of Mr. Reginald F. Hanks, M.I.Mech.E.

MR. J. L. NORTON, M.I.Mech.E., has been appointed chief mechanical engineer of Bristol Aircraft, Ltd., and is responsible for the design of mechanical assemblies on Bristol helicopters and fixed wing aircraft.

MR. E. G. CLARKE, managing director of Acheson Colloids, Ltd., has been elected to the board of directors of Acheson Industries, Inc., New York, and has been appointed to the office of vice-president, responsible for European operations.

DOULTON INDUSTRIAL PORCELAINS, Ltd., announces the following appointments in the commercial department of the insulator section at the Tamworth works: Mr. G. O. Hughes, contracts manager, and Mr. B. C. Cuddon, area representative for the Midlands, North of England, Scotland and Ireland.

METROPOLITAN-VICKERS ELECTRICAL COMPANY, Ltd., has announced that Mr. R. R. Whyte has been appointed assistant works manager (mechanical) and is responsible for the large and small turbine departments and the Germiston works, Glasgow. He remains assistant works manager of the Trafford Park works.

ELECTRO-HYDRAULICS, Ltd., has announced the following appointments: Mr. T. C. Wright, director and works manager; Mr. A. Harold, A.F.R.Ae.S., chief engineer. It has also announced the following appointments as directors of its subsidiary company, Conveyancer Fork Trucks, Ltd.: Mr. C. B. V. Neilson, M.I.Mech.E., M.I.E.E., A.F.R.Ae.S., Mr. R. Edwards and Mr. A. Harold.

MR. C. F. BARNARD has been appointed a director of the Brush Group, Ltd., executive vice chairman of Mirrlees, Bickerton and Day, Ltd., The National Gas and Oil Company, Ltd., and J. and H. McLaren, Ltd., deputy chairman of Associated British Oil Engines Marine (Mirrlees), Ltd., and Associated British Oil Engines Marine (National), Ltd. He retains his seat on the board of Brush Traction, Ltd.

THE BRUSH GROUP, Ltd., has announced the following appointments: Mr. Miles Beevor has relinquished the post of joint managing director but remains deputy chairman; Mr. Ian T. Morrow has been appointed managing director; Mr. Charles Barnard has been appointed a director with responsibilities for the group's heavy engine factories. Mr. M. C. Clear has been appointed a director and will take charge of exports.

Business Announcements

BRITISH INSULATED CALLENDER'S CABLES, Ltd., states that Mr. W. H. McFadzean, chairman and managing director, has left this country by air on a round-the-world tour.

VACU-BLAST, Ltd., has established a new company in France. It will be known as Societe Vacu-Blast (France), and its address is 46, Rue Anatole France, Levallois-Perret (Seine), France.

MARCO CONVEYOR AND ENGINEERING COMPANY, Ltd., has announced that Andrew McNair and Co., 261, West George Street, Glasgow, C.2, has been appointed sole agent for Scotland.

MR. A. P. EVANS, A.M.I.Mech.E., deputy chief engineer (mechanical) of the Crown Agents for Oversea Governments and Administrations, has left this country to pay a short visit to the Caribbean area.

D. NAPIER AND SON, Ltd., states that Amalgamated Wireless (Australasia), Ltd., 47, York Street, Sydney, N.S.W., is the Australian agent for Napier gas-turbine aero engines, rocket engines, and all other products with aviation applications. A separate agreement is being negotiated for the "Spraymat" anti-ice heating system.

BIRLEC, Ltd., states that a new heating division has been formed under the management of Mr. J. M. Paton, by the amalgamation of the furnace and induction heating divisions. Mr. D. A. Hackett has been appointed sales manager of the new division. A new engineering department has also been formed by the amalgamation of divisional drawing offices under Mr. G. H. Shirley, as chief engineer.

Contracts

HUDSWELL, CLARKE AND CO., Ltd., Leeds, has received an order for eight main-line diesel-hydraulic locomotives for the Sierra Leone Railway. Each of the locomotives is to be fitted with a Paxman diesel engine, together with a Vulcan-Sinclair "Dual-Fluidrive" transmission unit. The value of the contract amounts to over £200,000; it was placed by the Crown Agents for Oversea Governments and Administrations, acting for and on behalf of the Government of Sierra Leone.

THE BRITISH TRANSPORT COMMISSION has announced contracts in connection with the electrification of sections of British Railways under the modernisation plan. The total value of these contracts is about £8,000,000 and the details are as follows: Metropolitan-Vickers Electrical Company, Ltd., ninety-one sets of electrical equipments for multiple-unit train sets to operate on Glasgow suburban lines; The British Thomson-Houston Company, Ltd., thirty-five sets of electrical equipments for four-car, multiple-unit train sets to operate on Manchester–Crewe section; The English Electric Company, Ltd., 112 sets of electrical equipments for four-car train sets to operate on London–Tilbury–Southend section; The General Electric Company, Ltd., seventy sets of electrical equipments for three-car train sets to operate on Liverpool Street–Chingford–Enfield section. Contracts have also been placed for 25kV single phase, 50 cycle electrification switchgear for line-side installation on Colchester–Clacton and Manchester–Crewe sections as follows: Asea Electric, Ltd., twenty-five sets of 300MVA circuit breaker equipments and twenty-five sets of 150MVA circuit breaker equipments; Switchgear and Cowans, Ltd., fifty sets of 300MVA circuit breaker equipments and fifty sets of 150MVA circuit breaker equipments. British Brown-Boveri, Ltd., will supply 250 sets of circuit breakers for multiple-unit train sets for installation on Colchester–Clacton and Manchester–Crewe sections and other lines.

Miscellanea

FLEET FIGHTER.—Deck landing and catapult launching trials have been successfully completed by a Supermarine N.113, using "supercirculation." The trials took place on H.M.S. "Ark Royal," and showed an appreciable decrease in the approach and airborne speeds. The system of flap blowing avoids separation by injecting air from the compressors into the boundary layer through slots immediately in front of the flap: blowing is obtained automatically at flap angles beyond 10 deg., or can be manually selected.

ENGINEERING EXHIBITION AT OLYMPIA.—The Engineering, Marine, Welding and Nuclear Energy Exhibition is to be held at Olympia, London, from August 29 to September 12. It will be noted that "Nuclear Energy" has been incorporated in the title of this exhibition, which has been held biennially—apart from the war years—since 1906. The honorary president of the exhibition is Mr. W. K. G. Allen, and the organisation continues to be the responsibility of F. W. Bridges and Sons, Ltd., Grand Buildings, Trafalgar Square, London, W.C.2.

NORTHERN IRELAND CENSUS OF PRODUCTION.—According to the preliminary report of the Census of Production in Northern Ireland in 1955, the gross output of industry in that year amounted to £417 million, an increase of £38,000,000 compared with the previous year and the highest figure ever recorded. The number of people engaged in industry was 211,000, compared with 213,000 in 1954. The value of the total gross output rose by 10 per cent on the preceding year, and net output was up by 8 per cent, whilst employment declined by 1 per cent.

MAJOR DEVELOPMENT WORKS IN AUSTRALIA.—A revised edition of the Australian Department of National Development's booklet "Major Development Projects" lists 179 of Australia's major development schemes for water conservation and supply, irrigation, electricity generation, town gas, railway construction, sea ports, airports and land settlement. The booklet gives brief notes on the nature of each project, its purpose, the progress reached and, wherever possible, the estimated cost. The booklet also records projects completed in the various fields since the first edition was published in 1954.

INTERNATIONAL CONGRESS ON PRESTRESSED CONCRETE.—The next international congress on prestressed concrete will be held in Berlin from May 5 to 10, 1958. The executive committee of the Federation Internationale de la Precontrainte has chosen the following subjects for the working sessions:—Development in design methods (contributions dealing with experimental work on shear stresses are particularly requested); advances in the technique of site work, with particular reference to grouting, anchorages, reduction of friction and safety measures; progress in the manufacture of prestressed concrete units in factories and the use and assembling of precast units on the site; building and structures carried out wholly or partly in prestressed concrete since the 1955 congress.

INDUSTRIAL FLOOR COATING.—A liquid floor coating, suitable for use on concrete, stone and similar floors, has been introduced by "Exsud" South American Minerals and Products Company, Ltd., 26–7, Cowcross Street, London, E.C.1. It is known as "Exon" and has a polyvinal base emulsified in water; it is claimed by the manufacturers to resist both acid and alkali solutions of moderate strength and to remain unaffected by paraffin, kerosene, petrol, oil and grease. Under normal conditions the coating, which may be applied either by brush or with a spray, is said to be dry to the touch in thirty minutes. It is available in four colours, stone, grey, tile-red and white, other colours can be supplied to order.

DE-ICING METHODS.—Fokker Aircraft is offering two alternative de-icing systems for the F.27 "Friendship," one optional consisting of hot air anti-icing for the wings and cyclic electro-thermal de-icing for the tail unit, the alternative standard version having inflatable rubber boots for the leading edges of all flying surfaces. The first series of flight tests will be with the hot air/electrical system, which is being installed on the second prototype. Electrical de-icing is by Napier "Spraymat" (see page 420, March 19, 1954) and is used on the wing leading edges to protect the intakes of the combustion heater units and alternator cooling ducts. The application to the tail surfaces is unusual, in that the leading edges are constructed in polyester resin reinforced by glass cloth, and therefore the usual sprayed layer of insulation is unnecessary.

ROBERT BLAIR FELLOWSHIPS IN SCIENCE AND TECHNOLOGY.—The London County Council is inviting applications for the award of the 1957 Robert Blair Fellowship, which is tenable for one year of advanced study or research overseas in applied science and technology. The value of the award varies according to the country chosen by the person to whom the award is made and may be as much as £2000 if the country selected is Canada or the United States. Applications for the 1957 Fellowship should be made before February 28. Particulars and application forms can be obtained from the Education Officer (WA. 14), County Hall, London, S.E.1. Candidates must be natural born British subjects and at least twenty-one years of age. Fellowships are open to suitable candidates, men or women, who have been trained in applied science and technology, but preference is given to engineering science and to those who have completed a course of study in London institutions or who have been identified with the London teaching service. The Robert Blair Fellowships were established by the L.C.C. in 1925, in appreciation of the outstanding services given to the Council and the London teaching service by Sir Robert Blair, LL.D., who was the L.C.C.'s education officer from 1904 to 1924. The fund from which the Fellowships are provided originated from a sum of money which accrued to the L.C.C, as a result of munitions work undertaken in London technical colleges during the first world war.

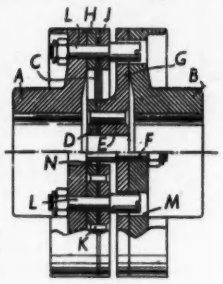
British Patent Specifications

When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification. Copies of specifications may be obtained at the Patent Office Sales Branch, 15, Southampton Buildings, Chancery Lane, W.C.2, 3s. each.

POWER TRANSMISSION

763,258. January 14, 1954.—FLEXIBLE COUPLINGS, Crofts (Engineers), Ltd., Empire Works, Thornbury, Bradford. (*Inventors: Horace Matthews and Frederick Oliver Ackroyd.*)

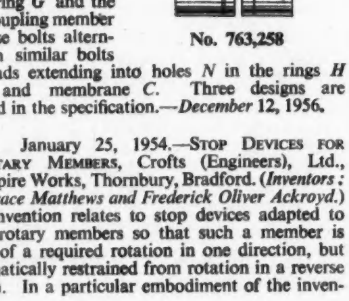
As shown in the drawing, two flanged main coupling members *A* and *B* have between them a flexible membrane *C*. This membrane is secured about its centre by a clamping ring *D* riveted to a detachable boss *E* secured to the member *B* by bolts *F*. The peripheral part of the membrane *C* is secured to the other coupling member *A* by being clamped between two rings *H* and *J*, held together by rivets *K* and secured in position by bolts *L*. These bolts have enlarged heads extending beyond the ring to enter holes *M* in the ring *G* and the other coupling member *B*. These bolts alternate with similar bolts with heads extending into holes *N* in the rings *H* and *J* and membrane *C*. Three designs are described in the specification.—*December* 12, 1956.

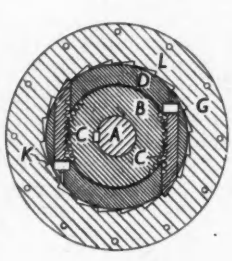


No. 763,258

764,293. January 25, 1954.—STOP DEVICES FOR ROTARY MEMBERS, Crofts (Engineers), Ltd., Empire Works, Thornbury, Bradford. (*Inventors: Horace Matthews and Frederick Oliver Ackroyd.*)

The invention relates to stop devices adapted to control rotary members so that such a member is capable of a required rotation in one direction, but is automatically restrained from rotation in a reverse direction. In a particular embodiment of the invention shown in the drawing, a stop device is constructed to suit a rotary member to be controlled to rotate in one direction only, which is shown as shaft *A*, but may be a sleeve or other member. The device itself includes a spur pinion *B* keyed on the shaft and teeth *C* are formed around the periphery of the pinion where required. A ring-shaped carrier *D* surrounds the pinion and is supported by a ball race *F*. This carrier ring is provided with two diametrically opposite blind holes *G* extending tangentially from its periphery, parallel with each other, but opening in opposite directions. Each hole breaks through into the bore of the ring *D*. Within these holes are located slidable racks *H*, which have teeth to engage with the pinion teeth *C*. With this arrangement the shaft *A* can rotate in one direction anti-clockwise in which the pinion *B* retracts the racks *H* into the carrier ring *D* so that the pinion, racks and carrier ring rotate as a complete unit. On any tendency for the shaft *A* to reverse rotation the spur pinion *B* will automatically slide the racks *H* out and their nose portions will engage as shown with the teeth *K* of a ratchet ring *L* surrounding the carrier ring *D*. This ratchet ring is held against rotation and is formed with a flange *M* bolted to a housing *N*, in which the stop device is located, or secured, to some other adjacent structure. The blind holes are provided with air escape holes to prevent the compression of air trapped as the racks are retracted. If it is desired to alter the direction of rotation of the shaft *A* the ratchet element *L* may be removed and replaced with the present upper face downwards, similarly the carrier ring *D* is removed and replaced with the reverse end supported by the bearing *F*. The device is suitable for controlling a vertically mounted electric rotor which supports the weight of, and drives, a water pump below ground level, which arrangement is also shown in the specification.—*December* 28, 1956.



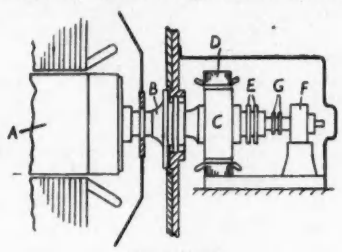


No. 764,293

ELECTRICAL ENGINEERING

764,046. January 18, 1955.—HIGH POWER ELECTRIC GENERATOR SETS, Siemens-Schuckertwerke Aktiengesellschaft, Berlin, and Werner-von-Siemens-Strasse 50, 13a Erlangen, Germany.

This invention relates to a high-power generator set, such as a high-power turbo-generator set. An object of the invention is to provide a turbo-generator in which, first, the axial length of the exciter set is considerably reduced and, secondly, the use of a high-speed, high-power d.c. machine is avoided. Referring to the drawing, a shaft end, from the rotor *A* of comparatively large diameter, of a generator projects from a turbo-generator end plate *B*. Fitted directly to the shaft end is a rotor *C* of a non-commutator a.c. exciter machine for supplying energy to the field windings of the generator, the polyphase winding of which exciter is fitted in a stator *D*, and supplies the exciter winding of the turbo-generator via rectifiers. Slip rings *E* necessary for this purpose are disposed on the right-hand side of the rotor (with regard to the drawings) and supply leads (not shown) extend from the slip rings through the turbo-generator shaft to the exciter winding. Also disposed on an extension of the end of the turbo-generator shaft is a rotor of an auxiliary exciter *F*, the brushes (in the case where it is a d.c. machine) or the stator windings (in the case where it is an a.c. machine) of which supply the excitation for the rotor *C* via slip rings *G*. The exciter machine overhangs the shaft. It will be seen that in this arrangement, first a coupling and, secondly, two bearings, are eliminated and, thirdly, the axial length required is reduced as compared with sets using a commutator machine as the main exciter. The overall length of the exciter set is, therefore, reduced very considerable. Modified designs are also shown in the specification.—*December* 19, 1956.

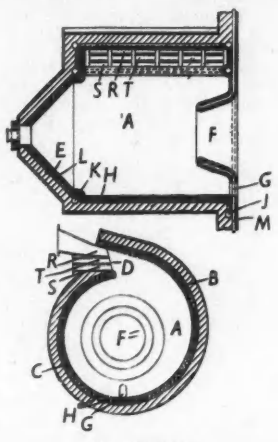


No. 764,046

STEAM GENERATORS

764,359. February 4, 1955.—CYCLONE FURNACES, Babcock and Wilcox, Ltd., Babcock House, Farringdon Street, London, E.C.4.

The invention relates to cyclone furnaces and to an improved method of burning low-grade fuel or of converting incombustible fly ash to slag. It will be seen from the drawings that the peripheral wall of the cyclone furnace chamber *A* is so formed that in cross section a part *B* of progressively decreasing radius merges into a part *C* of constant radius of curvature, thereby providing a nozzle aperture *D*. At one end, the chamber is closed by a frusto-conical wall *E* and at the other end is a gas outlet throat *F* and a slag outlet *G* leading to a secondary furnace chamber. The walls of the chamber are lined by vapour generating tubes connected into the circulatory system of a vapour generator of which the furnace forms part. Thus the peripheral wall of the furnace chamber is provided with tubes *H* extending between headers *J* and *K*, at the one end the wall *E* is provided with tubes *L* and at the other end wall tubes *M* of the secondary furnace chamber help to form the throat *F*. On their sides facing the flame the tubes have studs covered by refractory material, whilst on their outer sides the tubes of the peripheral wall and the wall *E* are covered by insulating material enclosed in a gas-tight, sheet metal casing. As shown by the upper view, six longitudinally spaced groups of inlet ducts or nozzles are provided and each group comprises a radially outer nozzle *R* connected to a source of secondary air; a radially inner nozzle *S*, connected to a source of carrier air and incombustible fly ash or low-grade fuel, and an intermediate nozzle *T* connected to a source of primary air and readily ignitable solid fuel in suitable form for entrainment by the primary air. The nozzles direct the streams tangentially or substantially tangentially with respect to the inner surface *B* of the furnace chamber wall and all in the same sense around the longitudinal axis of the furnace chamber and each group of nozzles discharges its three streams into the furnace chamber all at or substantially at one radial plane, appropriate to the group transverse to the longitudinal axis of the furnace chamber, that axis being at the centre of curvature of the part *C*. In operation, the fuel delivered by a nozzle *T* into the furnace chamber rapidly ignites and by centrifugal force passes into the high-velocity stream of secondary air delivered from the nozzle *R*, in which air the fuel burns at high temperature. The solid material delivered by the nozzle *S* also passes by centrifugal force towards the peripheral wall of the furnace chamber and, therefore, is intimately mixed with the secondary air and burning particles of readily ignitable fuel and subjected to the high temperature produced by the combustion of the fuel from the nozzle *T*. As a result, if the solid material from the nozzle *S* is combustible it is ignited and burns and the ash melts. The molten slag collected on the walls of the furnace chamber drains to the bottom and is evacuated through the outlet *G*. To effect good separation of the slag by centrifugal effect, a suitably high velocity must be maintained at the outlets from the secondary air nozzles *R*. The gases formed by combustion in the chamber *A* pass through the throat *F* into the secondary furnace, from which the molten slag is discharged in a suitable manner.—*December* 28, 1956.

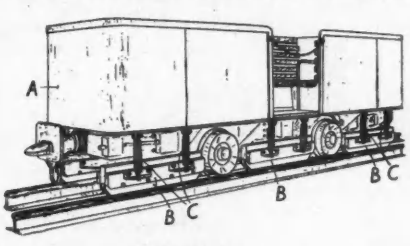


No. 764,359

MINING ENGINEERING

763,969. June 5, 1953.—PIT TRUCKS, Gutehoffnungshutte Sterkrade Aktiengesellschaft, formerly known as Gutehoffnungshutte Oberhausen Aktiengesellschaft, of Oberhausen (22a), Rhineland, Germany.

The invention relates to trains of trucks for underground and surface mine working. It consists of a pit truck train with an additional truck constructed to act as a brake truck, the brake truck having electromagnetic braking shoes controlled from the locomotive to produce a definite additional braking force independently of the weight of the truck superstructure or load. By means of such a brake truck the braking action of the driving engine itself is supplemented. As will be seen from the drawing the body of the vehicle is divided to carry passengers and equipment. On the underframe is the braking device, which consists of pairs of track brake shoes *B* suspended on springs *C*. The pairs of shoes may be disposed between the wheel sets or only adjacent the wheel sets at both ends of the truck. Preferably, the outer brake shoes are so dimensioned that they project to a small extent beyond the length of the truck. The brake shoes are actuated by electro-magnets which force them against the rail head, tensioning the springs, thereby producing a powerful frictional braking action.—*December* 19, 1956.



No. 763,969

Launches and Trial Trips

ZENATIA, oil tanker ; built by Cammell Laird and Co. (Shipbuilders and Engineers), Ltd., for Shell Tankers, Ltd. ; length between perpendiculars 675ft, breadth moulded 89ft, depth moulded 49ft, summer draught 36ft, deadweight 38,000 tons ; thirty-three cargo oil compartments, one main cargo pump room ; two 600kW turbine-driven alternators, one 150kW diesel-driven generator ; one set of h.p. and l.p. turbines, double reduction gearing, 16,500 maximum s.h.p., steam supplied at 600 lb per square inch and 850 deg. Fah. by two Babcock and Wilcox water-tube boilers.—Launch, October 23.

ONDO, cargo liner ; built by Harland and Wolff, Ltd., at Belfast, for Elder Dempster Lines, Ltd. ; length overall 450ft, length between perpendiculars 425ft, breadth moulded 62ft, depth moulded to shelter deck 34ft, gross tonnage 5435 ; two complete steel decks, eight watertight compartments, four main cargo holds, one 80-ton, one 30-ton and sixteen derricks to lift from 3 tons to 12 tons ; electric winches, four 125kW diesel-driven generators ; Harland and Wolff two-stroke, single-acting opposed piston diesel engine, five cylinders, 620mm diameter by 1870mm combined stroke, 115 r.p.m.—Trial, October 25.

TUSCANY, cargo liner ; built at Govan by Harland and Wolff, Ltd., for Royal Mail Lines, Ltd. ; length between perpendiculars 415ft, breadth moulded 58ft 6in, depth moulded to shelter deck 38ft 4in, gross tonnage 7455 ; three continuous decks, eight watertight compartments, five cargo holds, one 30-ton and fourteen derricks to lift up to 10 tons ; electric winches, three 150kW diesel-driven generators ; Harland and Wolff two-stroke, single-acting, opposed piston diesel engine, six cylinders, 620mm diameter by 1870mm combined stroke, 115 r.p.m.—Trial, October 25.

ALBANY, cargo ship ; built at Govan by Harland and Wolff, Ltd., for Royal Mail Lines, Ltd. ; sister ship to Tuscany.—Launch, October 31.

Catalogues and Brochures

ALLWEATHER PAINTS, Ltd., 36, Great Queen Street, London, W.C.2.—Leaflet describing "Pitakote" "Epikote"-based paint.

MARTONAIR, Ltd., Parkshot, Richmond, Surrey. Leaflet describing a series of automatic oscillating hoists with capacities up to 500 lb.

CORROSION, Ltd., Southampton. Folder describing "Glodane" cold galvanising, a method of applying a metallic zinc coating to iron and steel.

CHARLES RYAN AND CO., Ltd., 2–20, Capper Street, London, W.C.1.—Illustrated price list of compression joints for butane gas installations.

STURTEVANT ENGINEERING COMPANY, Ltd., Southern House, Cannon Street, London, E.C.4. Publication No. 9803, entitled "Lime Hydrating," giving details of the "Sturtevant-Knibbs" plant for the hydration of lime.

TECHNICAL CERAMICS, Ltd., Wood Burcote Way, Towcester, Northants.—Illustrated brochure giving technical information on ultrasonic materials. Details are given of the manufacture of barium titanate transducers and piezo-electric ceramics and some of their uses. A section is included explaining how design engineers can interpret piezo-electric effects to the best advantage for particular applications.

CABLE COVERS, Ltd., St. Stephen's House, Westminster, London, S.W.1.—Anniversary book, produced to celebrate twenty-one years of service to industry. Brief details of the history of the company are given and photographs illustrate some of the products and services available. The work of the power engineer's equipment division, the "Talurit" division and the prestressed concrete division is described.

BIRLEC, Ltd., Tyburn Road, Erdington, Birmingham, 24. Publication No. 76/3, entitled "Continuous Conveyor Furnaces," illustrating some of the major types of conveyor furnaces and many typical installations. This publication has recently been revised and now includes details of a new annealing furnace for silicon steel, a gas carburising plant, a battery of shaker hearth annealing furnaces and an automatic wire annealing furnace. Publication No. 65/3, describing the "Birlec Detroit" rocking arc electric melting furnace.

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office not later than a fortnight before the meeting. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

ASSOCIATION OF SPECIAL LIBRARIES AND INFORMATION BUREAUX

Wed., Jan. 30.—Royal Society of Arts, 8, John Adam Street, London, W.C.2, "Communication of Science by Means of Film," A. R. Michaelis, 6 p.m.

ASSOCIATION OF SUPERVISING ELECTRICAL ENGINEERS

Wed., Jan. 30.—BRIGHTON, HOVE AND DISTRICT BRANCH : New Imperial Hotel, First Avenue, Hove, "Valves," 7.30 p.m.
Fri., Feb. 1.—LIVERPOOL BRANCH : Liverpool Engineering Society, 9, The Temple, 24, Dale Street, Liverpool, 2, "X-Ray Production and Problems," L. C. Maple, 7.30 p.m.

BRITISH INSTITUTION OF RADIO ENGINEERS

Wed., Jan. 30.—LONDON SECTION : London School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, London, W.C.1, "Battery-Operated Frequency Modulation Receivers," R. A. Lampitt and J. P. Hannifan, 6.30 p.m., and "Design of Battery-Operated Radiac Equipment," K. E. G. Perry, 6.30 p.m.

BRITISH INTERPLANETARY SOCIETY

Sat., Feb. 2.—Caxton Hall, Caxton Street, London, S.W.1. "Accelerations in Flight," F. Latham, 6 p.m.

HULL CHEMICAL AND ENGINEERING SOCIETY

Tues., Jan. 29.—Hull Church Institute, Hull, Presidential Address, "De-odorization," L. H. Coulson, 7.30 p.m.

ILLUMINATING ENGINEERING SOCIETY

To-day, Jan. 25.—BIRMINGHAM CENTRE : Regent House, St. Phillip's Place, Colmore Row, Birmingham, "Lighting of Educational Institutes," A. G. Sheppard Fiddler, 6 p.m.
Mon., Jan. 28.—LEEDS CENTRE : E.L.M.A. Lighting Service Bureau, 24, Aire Street, Leeds, 1, "Lighting Installation Practice in Mines," W. B. Bell, 6.15 p.m.
Tues., Jan. 29.—EDINBURGH CENTRE : Scottish Lyceum Gallery and Restaurant, 11, Atholl Crescent, Edinburgh, 3, Joint Meeting with the Edinburgh Electrical Society, 7.30 p.m.

INCORPORATED PLANT ENGINEERS

Mon., Jan. 28.—BIRMINGHAM BRANCH : Imperial Hotel, Temple Street, Birmingham, "Fire Prevention," G. F. Goodman, 7.30 p.m.——WEST AND EAST YORKSHIRE BRANCH : Leeds University, Leeds, "Civil Engineering," R. H. Evans, 7.30 p.m.
Thurs., Jan. 31.—SHEFFIELD AND DISTRICT BRANCH : Grand Hotel, Sheffield, "The Care and Maintenance of Wire Ropes," 7.30 p.m.

INSTITUTE OF BRITISH FOUNDRYMEN

To-day, Jan. 25.—WALES AND MONMOUTH BRANCH : Engineers' Institute, Cardiff, "Flow of Metal into Moulds," Film, 6 p.m.——FALKIRK SECTION : Temperance Café, Lint Riggs, Falkirk, "Production of Alloy Iron Castings," D. Fleming, 7.30 p.m.
Sat., Jan. 26.—E. MIDLANDS BRANCH : College of Arts, Derby, "The Production of Castings for Aircraft Engines," C. W. Hicks, 6 p.m.
Wed., Jan. 30.—LONDON BRANCH : Constitutional Club, Northumberland Avenue, London, W.C.2, "High-Duty Iron Castings Production," C. R. van der Ben, 7.30 p.m.

INSTITUTE OF MARINE ENGINEERS

Mon., Jan. 28.—MERSEYSIDE AND N.W. SECTION : Old Swan Technical College, Liverpool, "Modern Marine Steam Turbines," J. H. Gooch, 7.30 p.m.

INSTITUTE OF METALS

Thurs., Jan. 31.—BIRMINGHAM LOCAL SECTION : Birmingham Exchange and Engineering Centre, Stephenson Place, Birmingham, "Pure Metals," J. C. Chaston, 6.30 p.m.

INSTITUTION OF CHEMICAL ENGINEERS

To-day, Jan. 25.—N.W. BRANCH : Grand Hotel, Manchester, Annual General Meeting, 3.30 p.m.
Sat., Feb. 2.—MIDLANDS BRANCH : Midlands Institute, Paradise Street, Birmingham, Annual General Meeting, 2.30 p.m.; "Automatic Control of Continuous Distillation Plant," E. J. Eaton and R. Parkins, 3 p.m.

INSTITUTION OF CIVIL ENGINEERS

To-day, Jan. 25.—YORKSHIRE ASSOCIATION : Hotel Metropole, Leeds, "Organisation and Control of Highways Maintenance," W. J. Hiscock, 6.15 p.m.
Tues., Jan. 29.—PUBLIC HEALTH MEETING : Great George Street, Westminster, London, S.W.1, "The Campaign for Cleaner Rivers," M. Lovett, 5.30 p.m.

INSTITUTION OF ELECTRICAL ENGINEERS

To-day, Jan. 25.—N.E. CENTRE : Carlisle Technical College, Carlisle, "Electrical Energy from the Wind," E. W. Golding, 7 p.m.
Sat., Jan. 26.—LONDON GRADUATE AND STUDENT SECTION : Visit to British Railways, Ilford Running Sheds, "Maintenance of Multiple-Unit Trains," 10 a.m.
Mon., Jan. 28.—E. ANGLIAN SUB CENTRE : Crown and Anchor Hotel, Ipswich, "The Potentialities of Railway Electrification at the Standard Frequency," E. L. E. Wheatcroft and H. H. C. Barton, 6.30 p.m.——N.E. CENTRE : Neville Hall, Newcastle upon Tyne, "Some Aspects of Heat-Pump Operation in Great Britain, with particular reference to the Shinfield Installation," Miriam V. Griffith, 6.15 p.m.——S. MIDLAND RADIO AND TELECOMMUNICATION GROUP : James Watt Memorial Institute, Great Charles Street, Birmingham, "The Control and Instrumentation of a Nuclear Reactor," A. B. Gillespie, 6 p.m.
Tues., Jan. 29.—MEASUREMENT AND CONTROL SECTION : Savoy Place, London, W.C.2, "An Experimental Study of High Permeability Nickel-Iron Alloys," C. E. Richards, E. V. Walker and A. C. Lynch, 5.30 p.m.; "A Method for the Precise Measurement of Permittivity of Sheet Specimens," A. C. Lynch, 5.30 p.m.; "A Bridge Network for the Precise Measurement of Direct Capacitance," A. C. Lynch, 5.30 p.m.; "A Simple Transformer Bridge for the Measurement of Transistor Characteristics," W. F. Lovering and D. B. Britten, 5.30 p.m.
Wed., Jan. 30.—SUPPLY AND MEASUREMENT SECTION : Savoy Place, London, W.C.2, "Power System Protection with particular reference to the Application of Junction Transistors to Distance Relays," and "A Dual-Comparator Mho-unit Distance Relay Utilizing Transistors," C. Adamson and L. M. Wedepohl, 5.30 p.m.——LONDON GRADUATE AND STUDENT SECTION : Visit to Ferranti, Ltd., Portland Place, London, W.1, Demonstration of "Pegasus" Computer, 2 p.m.——S.W. SCOTLAND SUB-CENTRE : Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, "Choice of Insulation and Surge Protection on Overhead Lines of 33kV and Above," A. Morris Thomas and D. F. Oakeshott, 7 p.m.

INSTITUTION OF ENGINEERING DESIGNERS

Sat., Jan. 26.—N.E. BRANCH : Visit to Dunston Power Station, 10.30 a.m.

INSTITUTION OF ENGINEERS AND SHIPBUILDERS

Tues., Jan. 29.—39, Elmbank Crescent, Glasgow, "The Education and Training of Technicians and Craftsmen in the Shipbuilding and Engineering Industries," S. Cormack, 6.30 p.m.; "The Education and Training of Technologists," D. S. Anderson, 6.30 p.m.

INSTITUTION OF HEATING AND VENTILATING ENGINEERS

Tues., Jan. 29.—LONDON ASSOCIATE MEMBERS, GRADUATES AND STUDENTS BRANCH : Junior Institution of Engineers, Pepys House, 14, Rochester Row, London, S.W.1, "Ventilation and Cooling of Railway Tube Tunnels," J. Reed, 6.30 p.m.

INSTITUTION OF HIGHWAY ENGINEERS

To-day, Jan. 25.—LONDON MEETING : Institution of Structural Engineers, 11, Upper Belgrave Street, London, S.W.1, "Snow," E. W. H. Vallis, 5.30 p.m.
Fri., Feb. 1.—N.E. BRANCH : Cleveland Scientific and Technical Institution, Corporation Road, Middlesbrough, "Modern Concrete Road Construction," D. R. Sharp, 7 p.m.

INSTITUTION OF MECHANICAL ENGINEERS

To-day, Jan. 25.—1, Birdcage Walk, London, S.W.1, General Meeting in Conjunction with the Automobile Division and the Internal Combustion Engine and Lubrication Groups, "An Investigation into the Mechanism of Oil Loss Past Pistons," P. de K. Dykes, 6 p.m. ; "A Study of Piston Ring Lubrication, "Samuel Eilon and O. A. Saunders, 6 p.m.
Sat., Jan. 26.—LONDON GRADUATES' SECTION : 1, Birdcage Walk, Westminster, London, S.W.1, "Some Highlights in the History of Mechanical Engineering," E. G. Sterland, 3 p.m.
Mon., Jan. 28.—E. MIDLANDS BRANCH : Rolls-Royce Welfare Hall, Derby, "Quality in Engineering," F. Nixon, Joint meeting with Derby A.D. Centre, 6.15 p.m.
Wed., Jan. 30.—AUTOMOBILE DIVISION : 1, Birdcage Walk, Westminster, London, S.W.1, Discussion on Economy in Commercial Vehicle Operation," 6.45 p.m.——S. BRANCH : Canteen of Transport Equipment (Thornycroft), Ltd., Basingstoke, "Overdrives," S. H. Ashby, 7.30 p.m.
Thurs., Jan. 31.—INDUSTRIAL ADMINISTRATION AND ENGINEERING PRODUCTION GROUP : Engineers' Club, Albert Square, Manchester, "Computer-Controlled Machine Tools," H. Ogden, 6.45 p.m.——WESTERN A.D. CENTRE : Royal Hotel, Bristol, "Servicing of Injectors," R. Lewes, 6.45 p.m.; "The End of a Piston's Life," A. C. Whitehorn, 6.45 p.m.; "Brakes," J. G. Remington, 6.45 p.m.——E. MIDLANDS GRADUATE SECTION : Technical College, Lincoln, "Power From Nuclear Energy," M. D. Wood, 7.15 p.m.——N.W. GRADUATE SECTION : L.C.P.T., 24, Hatton Garden, Liverpool, "Pneumatic Handling of Powdered Materials in the Food Industries," R. W. Allen and W. J. Farrand, 7 p.m.
Fri., Feb. 1.—AUTOMOBILE DIVISION : Dinner and Dance, Dorchester Hotel, London, W.1, 7.30 p.m.

INSTITUTION OF PRODUCTION ENGINEERS

To-day, Jan. 25.—S. WALES REGION : The Institute of Engineers, Park Place, Cardiff, "Human Relations in Industry," D. W. Collier, 7 p.m.
Mon., Jan. 28.—N.W. REGION : College of Technology, Manchester, "Rocket Propulsion and Its Application," J. Humphries, 7.15 p.m.
Tues., Jan. 29.—SOUTHERN REGION : Town Hall, Oxford, "The Use of Rubber in Engineering," A. N. Gent, 7.30 p.m.——S.E. REGION : S.K.F., Ltd., Luton, "Automatic Inspection," F. R. Boosey, 7.30 p.m.
Wed., Jan. 30.—N.W. REGION : Grosvenor Hotel, Chester, "Automatic Inspection : The Anatomy of Conscious Machines," John Sargrove, 7.30 p.m.——S.W. REGION: University Engineering Laboratories, University Walk, Bristol, 8, "Production Engineering in the Coal Industry," L. C. Tyte, 7.15 p.m.——SOUTHERN REGION : Southampton University, Southampton, "Atomic Energy for Aircraft Propulsion," J. E. Perkins, 7.15 p.m.——MIDLANDS REGION : Technical College, Shrewsbury, "Influence of Production Problems on Modern Machine Tool Design," C. A. Sparkes, 7.30 p.m.
Thurs., Jan. 31.—N. MIDLAND REGION : Ruston Club, Lincoln, "Valid Incentives," E. C. Gordon England, 7.30 p.m.

INSTITUTION OF PUBLIC HEALTH ENGINEERS

Mon., Jan. 28.—DISCUSSION GROUP : Denison House, 296 Vauxhall Bridge Road, London, "Automatic Control in Sewage Works," L. B. Escritt, 6 p.m.

INSTITUTION OF STRUCTURAL ENGINEERS

To-day, Jan. 25.—MIDLAND COUNTIES BRANCH : James Watt Memorial Institute, Birmingham, "The Calculation of Bending and Torsional Effects in Girders," J. S. Terrington, 6 p.m.
Fri., Feb. 1.—MIDLAND COUNTIES GRADUATES AND STUDENTS SECTION : Birmingham Exchange and Engineering Centre, Stephenson Place, Birmingham, "Erection Procedure, with special reference to Erectors' Problems," A. G. Osborne, 6.30 p.m.

INSTITUTION OF THE RUBBER INDUSTRY

Mon., Jan. 28.—MANCHESTER SECTION : Grand Hotel, Manchester, "Butadiene and its Copolymers," Maldwyn Jones and N. D. MacLeod, 6.45 p.m.

JUNIOR INSTITUTION OF ENGINEERS

To-day, Jan. 25.—INFORMAL MEETING : Pepys House, 14, Rochester Row, Westminster, London, S.W.1, "The Mechanical Aim and Progress in Fire Fighting Equipment," Edmund S. Calvert, 7 p.m.
Fri., Feb. 1.—INFORMAL MEETING : Pepys House, 14, Rochester Row, Westminster, London, S.W.1, "Trans-Ocean Deep-Sea Submerged Repeater Systems," E. F. S. Clarke, 7 p.m.

MANCHESTER ASSOCIATION OF ENGINEERS

To-day, Jan. 25.—Engineers' Club, Albert Square, Manchester, Joint Meeting with the Institute of Petroleum, "Smokeless Zones," General Open Discussion, 6.45 p.m.

NORTH EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS

To-day, Jan. 25.—Lecture Theatre, Mining Institute, Neville Hall, Newcastle upon Tyne, "A Method of Analysing Voyage Data," R. E. Clements, 6.15 p.m.
Wed., Jan. 30.—TEES-SIDE BRANCH : Cleveland Scientific and Technical Institution, Corporation Road, Middlesbrough, "Comprehensive Trials of Complete Marine Propulsion Turbine Installations," H. E. C. Hims, 6 p.m.

REINFORCED CONCRETE ASSOCIATION

Mon., Jan. 28.—SCOTTISH BRANCH : St. Enoch Hotel, Glasgow, "Applications of Prestressed Concrete," E. H. Goocey, 6.30 p.m.

ROYAL AERONAUTICAL SOCIETY

Tues., Jan. 29.—SECTION LECTURE : 4, Hamilton Place, London, W.1, "Design for Production," E. D. Keen, 7 p.m.

ROYAL INSTITUTION OF CHARTERED SURVEYORS

Mon., Jan. 28.—12, Great George Street, London, S.W.1, "Problems in Rural Planning," R. L. Stirling, 5.45 p.m.

ROYAL METEOROLOGICAL SOCIETY

To-day, Jan. 25.—SCOTTISH CENTRE : Department of Natural Philosophy, The University, Drummond Street, Edinburgh, "Generation of Sea Breezes," R. P. Pearce, 5 p.m.

SOCIETY OF INSTRUMENT TECHNOLOGY

Tues., Jan. 29.—MAIN MEETING : Manson House, Portland Place, London, W.1, "The Development of Instruments for Measuring the Performance of Steam Locomotives with the Mobile Testing Plant," H. I. Andrews, 6.30 p.m.

WOMEN'S ENGINEERING SOCIETY

Wed., Jan. 30.—LONDON BRANCH : Hope House, 45, Great Peter Street, London, S.W.1, "The Direct Use of Solar Energy," Harold Heywood, 7 p.m.

Advanced Engineering Courses

New Developments in Training. Fyvie Hall, 309, Regent Street, London, W.1. Course of five lectures for directors and senior executives, commencing January 10. Thursdays at 6.30 p.m. Fee : £2 15s.

Acoustics. Aeronautical Engineering Department, The University, Southampton. One-week course, April 1 to 6. Fee : £21 covers residence.

Mechanical Engineering. By Joseph H. Keenan. University of London, Senate House, Russell Square, London, W.C.1. Course of four lectures. February 14, 15, 18 and 21, at 5.30 p.m. Admission free.